THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Reservations

HAVE you made your reservation for the Summer Meeting? Six hundred and ten reservations had been received at the headquarters of the Society up to the time of going to press.

S.A.E. Handbook Issued

THE March issue of the S.A.E. HANDBOOK, which was mailed to members during the latter part of March, should have been received by them prior to the receipt of this issue of THE JOURNAL. Members who have not received their copies are asked to notify the Standards Department of the Society.

Summer Meeting Sports

THE Meetings Committee has appointed F. G. Whittington chairman of the Summer Meeting Sports Committee. The sports program includes golf, tennis, trapshooting, horseshoe pitching, baseball, track and field events, and archery. Suggestions as to any innovations in the sports program will be appreciated.

All-Ohio S.A.E. Day

ON Saturday, May 12, the Ohio State University Student Branch at Columbus, Ohio, will act as host to the members of the Society. The program for the meeting includes an inspection of the laboratory equipment, a luncheon, the Ohio State University versus the University of Chicago baseball game, or golf for those who prefer it, and a dinner-meeting at which F. F. Chandler, chairman of the Sections Committee, will present a paper, and President Hunt, Dean Hitchcock, John Younger and H. M. Jacklin will speak. All members of the Society are welcome.

Opportunities in the Automotive Industry

THE activities of the Society in stimulating the interest of embryo engineers in the automotive field have resulted in various student-group meetings. Members of the Society, well fitted to feature the opportunities in the automotive industry, have pointed out the pathways to a successful career in the industry.

The addresses heard by the students and their professors at the Student-Group Meeting held by the Metropolitan Section on Feb. 16, together with several organization charts featuring the ways to reach the higher positions in the organizations, are printed in full on p. 589 of this issue of THE JOURNAL.

Error in Nickel-Steel Specifications

ATTENTION is called to an error in the specifications for S.A.E. Nickel Steels No. 2015 and 2115 appearing in the table of nickel steels on Page D5 of the March, 1927, issue of the S.A.E. HANDBOOK.

The maximum sulphur-content for both steels now shown as 0.15-0.30 should read: Sulphur, maximum, 0.045. The figures now shown are for the silicon range which is given in the footnote on the same page.

The Sections Contest

THE Meetings Committee is arranging an inter-Section contest at the Summer Meeting that should prove of great interest to everyone attending the meeting. The winning Section will be the one whose team first assembles a light passenger-car chassis, gets the engine running, and drives the chassis five times around a short course in full view of the members and guests on the veranda of the hotel. Each chassis will be "disabled" to the same extent and will not require more than ½ hr. to assemble, only parts that affect the operating of the chassis being removed.

Full particulars of the Sections Contest will be found on p. 531.

Committee Meetings

THE Summer Meeting presents an ideal time for holding committee meetings. Arrangements are being made for meetings of the Nominating Committee, the Council, the Standards Committee, the Research Committee, the Meetings Committee, the Sections Committee, and several subcommittees. Special announcements of these meetings will be sent to the committee members in order that they may bring with them information necessary to act on the various matters to be discussed.

New Departments of the Journal

TO bring together as much as possible in an issue of THE JOURNAL items that are of particular interest to the production engineer, a new department has been instituted in this issue. Among the subjects which it is

planned to cover are the activities of the Production Division of the Standards Committee, the Production Advisory Committee and other general Committees of the Society bearing on production topics.

The Operation and Maintenance Department, the establishing of which was mentioned in the April number, is also inaugurated in this issue. This department will serve a similar purpose for the members of the Society interested in the operation and maintenance of motor-vehicle fleets and will include references to the work of the Operation and Maintenance Committee of the Society and other activities in this field of the automotive industry.

The Summer Meeting

THE technical program for the Summer Meeting is given on p. 532 of this issue. The Meetings Committee believes that this program warrants the attendance of every member of the Society, not alone because the meeting will present an opportunity for 4 enjoyable days, but because the engineering knowledge to be gained more than warrants the time and expense necessary to attend the meeting.

Without inspiration work becomes uninteresting and follows the line of least resistance. In an industry where success depends on continual development, inspiration is vital for men and companies that are to be successful. The Summer Meetings present an opportunity for engineers to obtain a better appreciation of conditions, to take stock of their knowledge and ability, and to determine new goals to work toward during the year. The companies benefiting by the work of such men will be the leaders in the industry.

Spectroscopic Fuel-Research

JUST as the results of the initial work of Dr. G. L. Clark, Lieut. W. C. Thee and H. L. Henne, in photographing the flames of motor-fuels marked, in the opinion of many, a new era in internal-combustion fuel-research by demonstrating the practicability of this method in the investigations of the causes and mechanism of detonation, thereby making possible a more intelligent analysis of the means for its control; and just as their papers based on these results have been considered, by those best able to judge, as truly among the foremost theses presented before the Society, so the contributed article by Lieutenant Thee in the Automotive Research department, p. 566 of this issue of THE JOURNAL, is meritorious and most timely in offering to those interested in this field a simple straightforward explanation of the spectroscopic method of study and the elementary principles of its practical application, thus enabling the engineer, though little versed in modern physics, to approach this most promising method of scientific investigation in the realm of motor-fuels with at least a modicum of understanding and an intelligent appreciation of experimental results and their useful interpretation.

Research in Engineering Colleges

PROFESSORS Potter and Young, of Purdue University, have carefully investigated research in engineering colleges. A report of their findings, as presented to the Society at the Annual Meeting, appears in this issue of the JOURNAL on p. 623.

Although the time devoted to pure research by the students of the universities occupies a comparatively small place in the curricula, and the results obtained are not of large immediate value, the importance of this work lies in the training of young men, some of whom are destined eventually to occupy high positions in the industry. The point has been well brought out that, although the United States leads the world in the practical application of basic principles to epoch-making inventions, the discovery of those basic principles has, for the most part, been made in the laboratories of other nations. The automobile industry needs engineers who, by training, are capable of

> Extending the frontiers of knowledge and of developing new processes for the conservation of the National research and the elimination of waste.

Although excelled by no other industry in the wholesale value of its products, the automobile industry lags far behind others in the support given to engineering colleges in special equipment and funds for the solution of new problems in research. In the language of the authors, such support

> Will improve the quality of the engineering-college graduate, advance basic knowledge in automotive engineering, and increase the supply of trained personnel for the research laboratories of the automobile industry.

The Nominating Committee

THE Nominating Committee is composed of one Member of the Society elected by each Section of the Society prior to the Summer Meeting, and three Members of the Society elected at the Semi-Annual Business Meeting. The members elected to date by the Sections are:

Section	*Member*
Buffalo	John C. Talcott
Chicago	O. W. Young
Cleveland	O. A. Parker
Detroit	L. M. Woolson
Indiana	F. F. Chandler
Metropolitan	S. R. Dresser
Milwaukee	William S. Harley
Pennsylvania	C. O. Guernsey
Southern California	E. B. Moore
Washington	A. W. S. Herrington

Of the three members-at-large elected at the Semi-Annual Business Meeting, no two may reside in the same Section territory. The Nominating Committee will be organized during the Summer Meeting. In recent years the names of the nominees for the elective offices have been announced during the Grand Ball. The Committee, however, has until Oct. 1 to make its report.

The success of any organization depends very largely on the ability and devotion of the officers elected to carry on its affairs. It is of course important that the members of the Nominating Committee consider carefully the requirements of the several offices and the qualifications of possible nominees.

The members of the Nominating Committee will doubtless appreciate suggestions regarding Members qualified to serve the Society as officers or members of the Council. Suggestions should be sent to them or the Committee direct.

SUMMER MEETING PROGRAM

SUMMER MEETING STARTS MAY 25

Exceptional Papers to be Presented and Interesting Sports Program Planned

A program that will present a physical impossibility for any one member to follow in its entirety will begin at 7 a. m. Wednesday, May 25, and end at 7 p. m. on Saturday, May 28. The technical program for the Summer Meeting is given on the following page. It includes eight technical sessions at which 20 papers will be presented. Members will find that practically all technical problems occupying the center of the automotive engineering stage at the present time are scheduled for discussion at these sessions. Members who expect to keep abreast with engineering development cannot afford to miss the papers to be presented at the Summer Meeting and the discussion that will follow their presentation.

The Summer Meeting presents the only opportunity for Society members to meet on a social basis. During the 4 days of the Summer Meeting the French Lick Springs Hotel will constitute the official home of the Society and the members, their wives and guests will constitute the official family. The program of sports and social activities is intended to give the members an opportunity to widen their acquaintanceship in the Society and industry.

The Inter-Section Automobile Contest

Without question the most outstanding contest ever staged at a Summer Meeting has been planned by the Meetings Committee for the afternoon of May 26. At 2 o'clock a single aerial bomb will be fired and immediately six teams of eight men, each representing one of the larger Sections of the Society, will tackle six Chevrolet chassis that will require about ½ hr. of practical engineering and generalship to put into running condition. On getting the chassis in running condition, the "chief engineers," who will be in command of the teams, will have to drive the chassis five times around a designated course. The Contest Committee is arranging for proper judges, inspectors and guards, and the checkered flag will signal the drivers starting their final lap.

The contest will be staged in front of the hotel veranda so that the members and guests will have an opportunity to watch the speed with which capable engineers and executives can take a large number of parts out of a box and find the proper place for each.

The members of the several teams will be supplied with white coveralls and caps which will have the name of their Section on the backs. The names of the members of the teams taking first, second and third place will be announced in the June issue of The Journal, together with the names of the parts each team had left over. The Contest Committee will not be responsible for the workmanship of any of the teams. Insofar as the contest is concerned, the only criterion of the workmanship will be the fact that the chassis complete the five laps as a self-propelled vehicle.

The "technical significance" of this event, in the opinion of the Contest Committee, is the possibility of simplifying car design. Every part left over will be studied by a special committee to determine the possibility of eliminating such parts in regular production.

The Meetings Bulletins

In order that the members may be well informed regarding the plans for the Summer Meeting, the Meetings Committee is publishing three Summer Meeting Bulletins. The first was mailed to the members on April 11 and covered the various events planned by the Sports Committee. The second or "Technical Issue" containing the complete technical program and information regarding the various papers was mailed on April 25. The last bulletin will be mailed on May 10 and will carry the last-minute news regarding the Summer Meeting plans, arrangements for special trains and cars and uptodate information on the road conditions from the various automotive centers. The last issue will contain also the railroad certificates that entitle the members to the fare and one-half privilege, which aids materially in cutting the cost of attending Summer Meetings.

The Prize Fund

Owing to the generosity of the companies with which members of the Society are connected, the Prize Fund for the Summer Meetings will take care of the prizes for the meeting this year and for the 1928 and 1929 meetings. The last prize fund was donated in 1925 and took care of the prizes for the Summer Meetings of 1925 and 1926, leaving a small surplus for 1927. The prizes constitute one of the most interesting phases of the Summer Meetings. They will be ex-

hibited during the meeting in the show-cases at the Information Desk, being marked to indicate what event each prize is for.

Bomb Time

Standard Time will be in force during the Summer Meeting, but members will have no need for their watches as the meeting will be run on "bomb time." At a quarter to the hours of 10 a. m. and 2 p. m. and 8 p. m. one aerial bomb will be fired to announce that technical sessions will convene in 15 min. This will give the members an opportunity to get to the sessions no matter what they may be doing or where they may be as the concussion will be loud enough to be heard all over the hotel and the lower golf course. To announce the beginning of a session, two bombs will be fired on the hour. Three bombs will be used to announce special events. The supply of bombs will be under lock and key to avoid danger of an *accidental* midnight bombardment.

The Inter-Section Championship Cup

The Inter-Section Championship cup is awarded each year to the Section whose members win the most points in the various sports events. The method of scoring is indicated by the figures in parenthesis in the list of events given below. The present Inter-Section Championship Cup was won by Detroit in 1926. The cup becomes the permanent property of the Section winning it three times. The sports events planned for the Summer Meeting follow:

MEN'S EVENTS

Golf Tournament (20-15-10-5)
Golf Driving Contest (5-3-1)
Golf Putting Contest (5-3-1)
Tennis Singles (10-5)
Tennis Doubles (10-5)
Trapshooting (10-5-3)
Horseshoes Singles (5-3-1)
Horseshoes Doubles (5-3-1)

Track Events

50-Yd. Dash, Men under 40 (5-3-1)
50-Yd. Dash, Men over 40 (5-3-1)
Fatman's Race (5-3-1)
Three-Legged Race (5-3-1)
Potato Race, Men under 40 (5-3-1)
Potato Race, Men over 40 (5-3-1)
Inter-Section Relay Race, Four-Man Teams (10-5-3)

Field Events

Shot Put (5-3-1)
Standing Broad Jump, Men under 40 (5-3-1)
Standing Broad Jump, Men over 40 (5-3-1)
High Jump (5-3-1)

LADIES' EVENTS

Golf Tournament (10-5-2-1)
Golf Putting Contest (5-3-1)
Clock Golf (5-3-1)
Tennis Singles (5-3-1)
Archery Contest (5-3-1)
50-Yd. Dash (5-3-1)
Bean Race (5-3-1)
Potato Race (5-3-1)
Egg Race (5-3-1)
Needle and Thread Race (5-3-1)
Throwing Baseball (5-3-1)
Bridge (5-3-1)
Treasure Hunt
Sightseeing Trips

S. A. E. SUMMER MEETING TECHNICAL PROGRAM

Wednesday, May 25

2:00 p. m.—STANDARDS COMMITTEE MEETING
8:00 p. m —SEMI-ANNUAL BUSINESS MEETING
Presidential Address, J. H. Hunt
9:00 p. m.—GENERAL SESSION
The Structure of the Atom—Dr. E. F. Barker, University of Michigan
Prize Winning Paper—Detroit Section
China—C. H. Robertson

Thursday, May 26

10:00 a. m.—CHASSIS SESSION
Pitch; Toe-In and Caster—J. E. Hale, Firestone Tire & Rubber Co.
Four-Speed Transmissions—S. O. White, Warner Gear Co.
8:00 p. m.—HEADLIGHTING SESSION
Factors Affecting Road Illumination—R. E. Carlson and W. S. Hadaway, Edison Lamp Works of the General Electric Co.
Focusing Mechanisms and Adjustments—A. W. Devine, Registry of Motor Vehicles, Commonwealth of Massachusetts
Double-Adjustment Head Lamps—W. W. Matthews, Motor-Vehicle Department, State of Pennsylvania

Friday, May 27

10:00 a. m.—RESEARCH SESSION
Relation of Research to Industry—W. S. James, Studebaker Corporation of America
Report on Detonation Survey—H. K. Cummings, Bureau of Standards
Engine Acceleration Tests—J. O. Eisinger.
Specifications for Petroleum Lubricants—Dr. M. R. Schmidt, Standard Oil Co. of Indiana
Strength of Spline Fittings—C. W. Spicer, Spicer Mfg. Corporation
2:00 p. m.—ENGINE SESSION
Oil-Flow through Crankshaft and Connecting-Rod Bearings—S. W. Sparrow and Donald B. Brooks, Studebaker Corporation of America
Valve-Spring Surge—W. T. Donkin and H. H. Clark, Cleveland Wire Spring Co.
8:00 p. m.—PASSENGER-CAR SESSION
Body Designing—A. E. Northup, Murray Body Corporation
An Experimental Development in Light-Weight Design—P. B. Jackson

Saturday, May 28

10:00 a. m.—BRAKE SESSION
Internal Brakes—H. D. Church, White Motor Co.
Brake-Lining Tests—S. Von Ammon, Bureau of Standards
Brake-Testing and Adjusting—F. W. Parks, Cowdrey Brake Tester Organization
2:00 p. m.—ENGINE SESSION
Effect of Legislation on Design—D. C. Fenner, International Motor Co.
Road Failures of Electrical Apparatus—D. P. Cartwright, North East Electric Co.

FORE

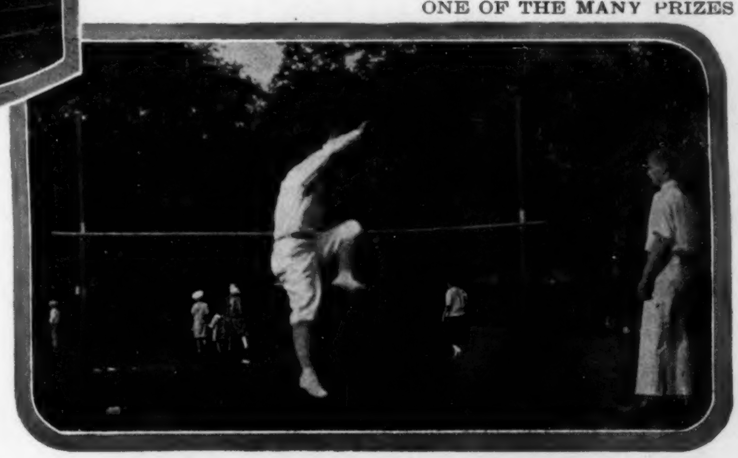
ON YOUR MARK

AIRPLANE VIEW OF HILL COURSE

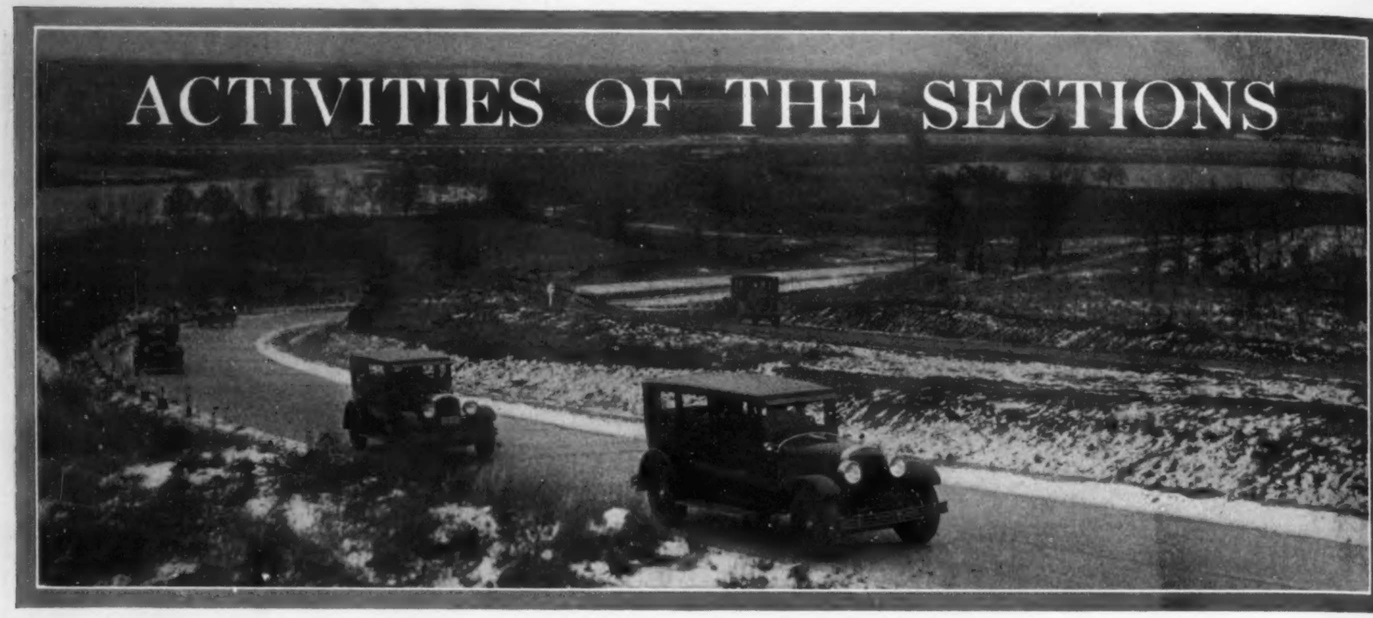
ONE OF THE MANY PRIZES

THE 50-YD. DASH

RETURNING A HARD DRIVE



BREAKING ANOTHER S.A.E. RECORD



BUILDING HIGHWAYS TO SUIT VEHICLES

Dr. T. R. Agg Suggests Reversing Usual Procedure to Metropolitan Section

What is the best type of highway for heavy traffic? A concrete road 12 in. thick that has about 40 lb. of steel reinforcement per square, is laid in lanes about 10 ft. wide, is articulated so that more lanes can be added if desirable, is provided with expansion-joints every 35 ft., and has some kind of filler for the joints to take care of changes of temperature. Dr. Thomas R. Agg thus replied to a query during the discussion at the regular monthly meeting of the Metropolitan Section at the Woodstock Hotel, New York City, on April 21, after presenting his paper on Building Highways To Suit the Vehicle. This meeting was an innovation in the usual program of Metropolitan Section meetings, in that, instead of discussing the design and construction of motor-vehicles to meet road conditions, the construction of roads to meet the needs of heavy vehicles was debated. Preceding Dr. Agg's talk, W. J. Davidson, engineering executive of the General Motors Technical Committee, and O. T. Kreusser, director of the General Motors Proving Ground, described the methods of making scientific road-tests at the Proving Ground, the subject being profusely illustrated with still and motion pictures. Chairman F. K. Glynn, after calling the meeting to order, introduced A. D. T. Libby, member of the papers committee, at whose suggestion the meeting was held, who presided.

Dr. Agg, who is chairman of the Committee on Economic Theory of Highway Improvement of the Highway Research Board of the National Research Council, highway engineer of the Iowa Engineering Experiment-Station, and professor of highway engineering at Iowa State College, Ames, Iowa, said in part that the World War, which brought about many changes in economic and social conditions in the United States, may be credited with having ushered in a new era in highway construction, although several years were required for the new ideals to gain general acceptance. The impetus to scientific highway construction has been due, in large measure, he said, to a realization of the significance of war-time experiences with highway transportation.

For a long time, declared Professor Agg, highway officials insisted that motor-vehicles must adapt themselves to the highway. Now the highway departments are endeavoring to adapt the highway system to the traffic. Because of the large present investment in highways and the urgent need of additional mileage of surfaced highways, limitation of loads and of the sizes of vehicle must of necessity continue as a safeguard to the existing investment in highways; but regulations in this regard are made as liberal as conditions allow. This new conception of the function of highway systems has made it imperative that highway engineers obtain a clear understanding of the interrelation of the highway and the vehicle that uses it; in other words, the effect of the vehicle on the road and of the road on the vehicle.

Effects Produced by Tires

Among the effects produced by tires on the road Professor Agg enumerated the following:

(1) The tires wear away the surface of the road due to the tangential force applied by the driving-wheels and the wheels that are equipped with brakes
(2) Wheel loads tend to distort the road surface and to depress it into a dish-like form
(3) Wheel loads subject road surfaces to varying degrees of impact

On the other hand the road surface has certain effects on the vehicle, and these should be properly evaluated in developing a highway system. This may be done in many instances without cost to the public by selecting the right kinds of surface for the several links in the highway system. Among these effects are the following:

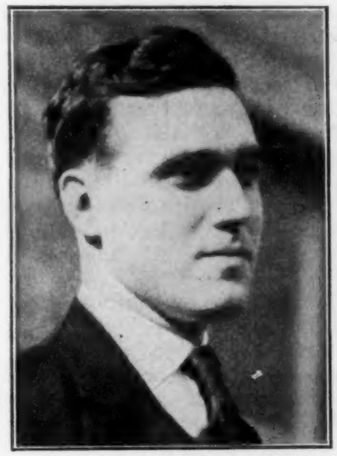
(1) The road surface offers a resistance to the movement of the vehicle in the form of an interaction between the tires and the surface of the road. This interaction, usually termed rolling resistance, on smooth hard unyielding roads is a little greater than the equivalent of the power losses in the tires, or approximately 30 lb. per ton of weight on the tires, but in extreme cases may reach several hundred pounds per ton
(2) The road surface wears away the rubber of the tire-tread and may be the determining factor in the life of the tire. Intermediate and low types of road surface wear the tires at a rate from 4 to 10 times that of the high-type surfaces, and certain surfaces of loose angular stone may produce 20 times the wear of the high-type surface
(3) When a road surface receives impact from a vehicle, the vehicle also receives impact from the road. The resulting forces are mutually destructive
(4) The rate of grade of a highway may affect the time of travel and the fuel consumption of the vehicle. Among the significant factors entering into the calculation of the most economical grade for a specific vehicle are the maximum tractive effort of the vehicle at the speeds considered, and

rolling and air resistance. As a general principle, the most economical grade may be said to be one that will allow a vehicle to ascend in high gear at the most efficient engine-speed and to descend without the use of brakes and without attaining too great a speed

(5) Slipperiness frequently contributes to accidents. The coefficients of friction vary little on accepted types of road surface when they are dry, but moisture and frost may produce very dangerous conditions

(6) Dust and mud produce deterioration of the vehicle. The exact cost of the depreciation and repairs chargeable to dust and mud has not been established, but a fair approximation is probably between $0.01 and $0.02 per mile for automobiles

The interrelations between the vehicle and the road afford a starting-point for the design of a highway, but theoretical considerations must often be modified to meet such practical considerations as available funds, topography, cost of right of way, and especially the lethargy of public officials toward that which is new or abstruse.



O. T. Kreusser T. R. Agg

TWO SPEAKERS AT THE APRIL MEETING OF THE METROPOLITAN SECTION
Mr. Kreusser Described the Car-Testing Routine at the General Motor Proving Ground and Professor Agg Suggested Building Highways To Suit Vehicles

FACTORS IN LOCATING A ROAD

In determining the location of a road, said Professor Agg, the major factors are directness, grades and safety. Over heavily traveled roads each foot of distance saved will justify an expenditure of at least $60. This saving must be borne in mind when the shortening of distance entails heavy grading or other expense.

In laying out grades, if there is any interesting road or other speed-limiting condition near the bottom of a hill, it is possible to utilize the momentum effect. When a road grade requires the shifting of gears and excessive use of the brakes, extra cost for gasoline and tire wear will result, the magnitude of which can be estimated. This extra cost, however, may be much less than that of traveling the extra distance required to secure lower rates of grade.

Notwithstanding the wide-spread adoption of the thickened-edge type of cross-section for concrete roads advocated in the report on the Bates experimental road, continued Professor Agg, the tendency has been to hold the thickness of slab to the minimum, regardless of the style and the climatic conditions of service. The logical basis of design seems to be the use of a concrete mixture that will give only the necessary resistance to wear, and to design the thickness of the slab on a basis of the modulus of rupture of the concrete thus obtained. Although slabs of uniform strength of the thickened-edge type have been widely adopted for concrete roads in preference to slabs of uniform thickness, this feature of design is not so common in a design of the concrete base for sheet or block pavements, although the same principles undoubtedly apply. The use of steel embedded in concrete bases merits wider adoption than it has received up to this time. The pavement should also be strengthened at the expansion-joints, for when this is not done the design is seriously unbalanced.

CLASSES OF ROAD SURFACE

Road surfaces are divided into three classes, according to Professor Agg, namely,

(1) Low type, comprising natural-soil roads and those composed of sand-clay, light gravel, oiled earth, shale, shell, and similar materials

(2) Intermediate type, including heavy gravel, surface treated gravels and macadams, water-bound macadam, and light bituminous macadams of various kinds

(3) High type, consisting of concrete, asphalt, block pavements with concrete base, heavy bituminous macadams and the best of the block-base types

Professor Agg called attention to the fact that the relative costs of the three types of pavement are more significant than the actual costs. The cost of any type of road is the aggregate of the expenditure required to build that type of surface and to keep it in a condition of maximum serviceability over an indefinite period of years. This cost includes the original cost, together with interest on the investment, maintenance and interest, and depreciation.

On analysis, the lower-type roads seem to be actually cheaper than those of the higher type for any traffic density under which the road could be maintained in good condition. Justification for road improvement must, therefore, be the creation of wealth rather than the conserving of road funds. The wealth produced by road improvement may be direct, in the form of lowered transportation cost, or indirect, as a result of improved social and educational conditions brought about through the improvement.

In conclusion, Professor Agg stated that the possibilities of lowering the cost of highway transportation should be of two kinds: namely, road improvement, by which the cost of vehicle operation is reduced to the economic minimum, and improvements in the vehicle, by which its life is lengthened and the operating costs are made as low as possible. The future trend of highway transportation, therefore, depends largely upon the highway engineer and the automotive engineer, who jointly will evolve roads and vehicles so well harmonized that the cost of highway transportation will be at the lowest possible rate.

CREEPING OF THE ROAD SURFACE

Professor Agg illustrated his talk with numerous slides and in explaining them extemporaneously brought out several additional features. He called attention to the creeping of the road surface, which is a factor accompanying the action between the wheels and the road surface under heavy traffic, a tendency of this shearing action being to wear away both the road surface and the tires; but with high-grade types of surface, the tire wears away much more rapidly than does the road surface. Another effect of the load upon the surface is to distort the surface to a form somewhat resembling a saucer. The ordinary theories of slab strength cannot be taken as safe in all respects, said Professor Agg, and in many cases the slabs are of insufficient thickness to give the requisite factor of safety under heavy traffic-conditions. The impact stresses produced on rough stone-block surfaces by different types of tire increase with the number of impacts, so that the stress is almost double that which would be produced by a vehicle standing still. To overcome this impact effect, enough stability must be built into the road to withstand the additional stress put upon it. This effect is reduced, of course, by increasing the smoothness of the road.

THE GENERAL MOTORS PROVING GROUND

Mr. Davidson described the experiences of H. M. Crane and himself in endeavoring to make tests of a new model

of car before the establishment of the present proving ground and stated that Mr. Crane decided at that time that $1,000,000 would be cheap for such a proving ground.

Mr. Kreusser showed several reels of motion pictures, illustrating the methods of testing various features of motor-cars, such as appearance, performance, reliability, comfort, durability, and the like. A program of analyses is carried on through a regular ritual to determine what a motor-car actually does in the customer's hands. The information thus available is used as a yardstick to determine the service that each car must give in order to show greater value than those that have preceded it.

The proving ground, said Mr. Kreusser, consists of a rough piece of terrain 1.5 miles square, in which are about 12 miles of gravel roadway, 4 or 5 miles of concrete road-day and some concrete hill-roads that have been very accurately graded. The object of the road system is to provide a practical roadway that will be safe for operation either at low speeds or at very high speeds. During the 7,000,000 miles that the cars have been operated no accidents of importance have occurred. Cars are operated night and day, winter and summer, with the object of making the data obtained during a 3-months' test as valuable as possible. On some days, 2000 gal. of gasoline is consumed and the grand average for the year is about 1500 gal. per day. Tests of experimental cars are carried out by the particular division involved by those who are responsible for the design, engineering, testing, production, sales, and service of the cars. In addition, tests of many other makes of automobile, both foreign and domestic, are made with the idea of evaluating definitely what the customer demands in seat comfort, durability, headlighting, vision, and many other factors.

The traffic density on the speed loop last year, said Mr. Kreusser, was 3 cars per min., 24 hr. per day, 365 days per year. In March, 1927, 509,000 miles was run "inside the fence" and more outside. Among those that took part in the discussion of Professor Agg's paper were E. E. Reed, assistant State highway engineer of New Jersey; E. P. Goodrich, consulting engineer, New York City; L. M. Whitcraft of the Portland Cement Association; and J. A. Anglada.

MODERN AIRPLANE POWERPLANTS

L. M. Woolson Describes Recent Developments at Milwaukee Section Meeting

Modern airplane powerplants, described and illustrated with slides by L. M. Woolson, aeronautical research engineer, Packard Motor Car Co., furnished the attraction that drew an attendance of 120 members and guests to the monthly meeting of the Milwaukee Section, held at the Milwaukee Athletic Club on April 6. The meeting as usual was preceded by a dinner. As the slides were thrown on the screen, Captain Woolson first showed the process of assembling and testing airplane engines, then described the details of construction of the various types of engine being built at present by his company and closed with a resume of the discussion regarding the comparative advantages of water-cooled and air-cooled engines. Following his presentation, a lively discussion showed the interest aroused by the subject and served to bring out additional points. Among the views shown were those giving the details of construction of the 600-hp. direct-drive engine, which is used in high-speed super-airplanes. This engine, when operating with extra high compression and running at 2700 r.p.m., can develop 700 hp. As its weight is 740 lb., the weight per horsepower is about 17 oz. The total weight is about the same as that of the average six-cylinder engine used in medium-sized automobiles, but the airplane engine develops 10 times as much power as the automobile engine. Five such airplane engines weigh no more than an average medium-sized passenger car but represent 3500 hp., or more power than the largest locomotive.

Other slides showed the Model-1500, both direct drive and geared; with both magneto and battery ignition; inverted as adapted to pursuit work, and as used in Navy Loening Amphibian airplanes; the Model-2500, both direct drive and geared; the FB-5, the new Navy Boeing pursuit airplane, equipped with the Model-1500 engine; the Douglas Corps Observation airplane and the Curtiss observation airplane similarly equipped; the Loening Amphibian airplane, equipped with the inverted Model-1500 engine; the PN-9 carrying two Model-1500 geared engines; the R3C3 Curtiss racing airplane; the new experimental Boeing pursuit airplane; the Glenn Martin three-purpose airplane, using the Model-2500 engine; the Martin T3M2 airplane, and the Huff-Daland Cyclops airplane.

WATER-COOLED VERSUS AIR-COOLED ENGINES

Referring to the comparative merits of water-cooled and air-cooled engines, Mr. Woolson said that although their requirements overlap to a certain extent, the field of each type is fairly well defined and each type in the present available sizes and forms has its particular sphere of usefulness. In the smaller airplane class, for either commercial or military purposes, the air-cooled engine is undoubtedly the more desirable of the two because of its greater simplicity, less expense and easier maintenance; and when the projected area of the engine is not substantially greater than the projected area of the fuselage at its largest section, no loss of performance of the airplane is incurred and ample gain may be secured because of the lower installed weights, as compared with that of some water-cooled engines. When faster airplanes are considered, however, such as the military pursuit type, the performance at high speed is seriously interfered with if the projected area of the engine exceeds that of the fuselage. The builders of air-cooled engines lay particular stress on maneuverability, but, as this depends largely on design, there is no evidence to show that an air-cooled-engined pursuit airplane will outperform one equipped with a water-cooled engine, assuming that both are equally well designed and have approximately the same wing-loading. In the heavy-duty class, in which the engine is compelled to run wide open for long periods and, in many cases, with the propeller geared to run at one-half the engine speed, thus decreasing the velocity of the slip-stream, Mr. Woolson asserted that the water-cooled engine stands supreme.

As the limitation that determines the maximum load is the ability to take-off from either land or water, any airplane of conventional design that can be induced to stagger off the ground or the water with an extremely heavy load can operate with the engines throttled as soon as it gets into the air, because the wheel-rolling resistance, or the skin friction of the water, is removed as soon as the airplane gets into the air. The whole problem is one of take-off.

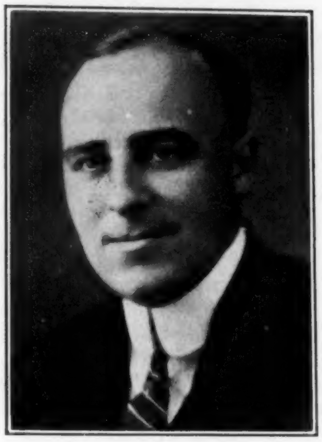
The geared Packard Model-2500 engine, as used in the Cyclops, the largest single-engined bombing airplane in the world, continued Mr. Woolson, exerts a ground or static thrust of 5000 lb., whereas all air-cooled engines, being of the direct-drive type, have a maximum propeller-thrust of about 1500 lb.

In conclusion, Mr. Woolson maintained that inasmuch as all world's records for airplane flight, including duration, distance, load carrying, altitude, and high speed, have been made by water-cooled engines, these engines have been indisputably proved to be supreme when real performance is required. The field of the air-cooled engine, he said, is in light-duty work where simplicity is more important than performance.

OIL INDUSTRY PICTURED

Production and Refining Shown in Motion Pictures and Described at Detroit

Four reels of motion pictures of the petroleum industry were displayed in connection with a cursory description of refining processes given by Dr. R. E. Wilson, member of the research council of the Standard Oil Co. of Indiana, at the April 7 meeting of the Detroit Section. Following the taking charge of research and development work in chemical engineering for the Company by Dr. Wilson in 1922, the company built an excellent engine laboratory about 1½ years ago in which many interesting results have been obtained of late. As a result of his experience as consulting chemical engineer for the Bureau of Mines in 1917 and 1918 and director of the research laboratory and professor of chemical engineering at the Massachusetts Institute of Technology from 1920 to 1922, when he specialized on fuel volatility, antiknock materials and lubrication, Dr. Wilson is a recognized authority on these subjects.



R. E. Wilson

In his address at the Detroit meeting he first spoke of the similarities and differences of the automobile and petroleum industries. Their rapid growth has been contemporaneous; the automobile industry could not have grown very fast without gasoline, he pointed out, and the petroleum industry could not have expanded as it has done except for the automobile, which now takes more than one-third of the total production of gasoline. One striking contrast is the ratio of labor cost to cost of finished product; in the automobile industry it is from 30 to 35 per cent, whereas in the petroleum industry it is only 6 per cent. Another difference is that the former industry is handling solid materials and must use a great deal of care in arranging the flow-sheet, whereas the petroleum industry is dealing with liquids and takes an inventory every day of materials on hand. It does not have to shut down to take an inventory, nor to take an inventory as an excuse for shutting down. One of the big advances made has been the stabilizing or proportioning of refining with sales, as the industry has no control over its raw material.

Formations in Which Oil Occurs

No one knows precisely the mechanism by which petroleum is formed, although it is known to be a decomposition of animal and vegetable remains below the surface of the earth, continued Dr. Wilson. It is found in three different rock structures: (*a*) the simple dome formed by folds in the rock, which is in three layers, with the top part of the structure eroded away; (*b*) the fault plane, in which a non-porous structure blocks a porous structure on the side of the fault on which the rock slopes away; and (*c*) the salt-dome structure, which occurs mainly in Texas, where some natural force has upheaved great domes of salt and blocked the oil passages through the porous earth. The locating of these salt domes is now done scientifically by exploding a charge of dynamite and recording by seismographs refracted earth tremors from the dome. Whether or not a well first strikes oil or gas depends upon where the drill strikes the dome. If the structure is penetrated to one side and below the gas, the oil is forced by the gas pressure to flow to the surface; otherwise, after the gas flows off first, the oil must be pumped.

Crude petroleum is a mixture of hydrocarbons that have different boiling-points, ranging from 75 to 1200 deg. fahr. A certain percentage of a given crude boils at temperatures up to 400 deg. and because of this low boiling-point is suitable for use as gasoline, or motor fuel. Overlapping this range to some extent is a percentage that is suitable for kerosene, which has an initial boiling-point of 300 deg. Lubricants boil, for the most part, between 800 and 1100 deg. Above the last temperature is the asphaltic material, with its high boiling-point.

Because of the great demand for kerosene from 1905 to 1910, the percentage taken out for gasoline was a relatively small amount of the lowest-boiling material; practically all of the rest went into kerosene, which represented about 40 per cent of the crude, while gasoline represented only 10 per cent. As the demand for gasoline increased, more of the potential gasoline was utilized as such, and kerosene distillation was started at an initial temperature nearer 400 than 300 deg.

The elimination from kerosene of the lighter end made it necessary also to leave out some of the heavier end to preserve the balance or gravity of the kerosene. If distillation of gasoline is carried much higher, therefore, almost no kerosene will be left. When both gasoline and kerosene are taken off, reduced crude fuel-oil remains. If the process is stopped at this stage, it is known as a skimming operation; but a very small cut of gas oil can be made and then the heavy asphalt is coked by simple cracking. The three processes are known as (*a*) skimming, (*b*) running down to coke and (*c*) running with steam to obtain the maximum volume of lubricants.

Great Improvements in Cracking Process

Cracking of the heavy material is an old process and can be conducted at atmospheric pressure, under which condition all the oils distill out as soon as formed, with a considerable proportion in the gas-oil range. The cracking increases the volume of oil, so that slightly more than 100 gal. is derived from 100 gal. of crude petroleum.

The first commercial method of making large quantities of gasoline was simply to heat the crude under pressure in the still for 24 hr. In this process it was necessary to use a "run-back," which condensed the kerosene and heavier products and allowed only the gasoline to come off. Twenty-five per cent of the gasoline can be taken off without trouble, but with direct fire only about 50 per cent can be distilled because of the danger of the bottom of the still becoming red hot. Hence a still with a water bottom is used now and only the tube is fired. Coke is deposited on the unfired surfaces but does no harm, although it accumulates in the still and prevents carrying the process as far as is desired.

The third system is to pass the crude oil in a more continuous flow through a heating coil in the furnace and then over a soaking ground under a higher pressure. By this method a large body of oil can be held at a sufficiently high temperature to produce a large extent of cracking, said Dr. Wilson. The limiting factors are the coke-holding capacity and the drop in temperature. It was found that, by mounting stills vertically, firing between the ends of the stills, and rotating scrapers inside to keep the sides of the still free from coke, the stills can be run continuously for a month and from 1500 to 1600 bbl. of crude oil passed through each cracking still per day. In the old original stills one was lucky to get 200 bbl. in 2 days. The new type of still, concluded Dr. Wilson, produces about 75 per cent of gasoline, 20 per cent of heavy tar, and 4½ per cent of gas and coke. The differential between gas oil and gasoline never will be very great from an economic consideration.

Questions Indicate Fuel-Shortage Apprehension

Discussion after delivery of the address was confined to questions put to and answered by the speaker. Supplemental information thus given was that oil derricks in a given field usually penetrate to the same oil sand; transportation of the crude by pipe-line costs about half as much as by rail and is about 60 cents per bbl. from the Mid-Continent field to Whiting, Ind.; some wells are down to a depth of 1½ miles and some old abandoned wells are now being sunk to lower depths; this Country produces about 71 per cent of the crude oil, Mexico about 9 per cent, Venezuela 6 per cent, Russia

5 per cent, Roumania 2 per cent and Colombia 1 per cent; Africa has not been thoroughly investigated but does not hold much promise; paraffin-base oils occur in West Virginia and Pennsylvania, pure asphaltic oils containing no paraffin occur in the Gulf States and California, and mixed-base oils are found in the Mid-Continent field; and the coal and shale are a reserve to which we shall have to look in the future, but to obtain from shale the amount of oil we are now producing would require the development of a mining industry somewhat larger than the present coal-mining industry.

Wants Papers on the 1937 Car

Preceding the address by Dr. Wilson, the chairman of the meeting, W. R. Griswold, reminded the attending members of the $100 prize offered by L. M. Woolson for the best paper submitted to the Section by any member of the Society on The Car of 1937. The contest closes soon, he said, and several papers that have been submitted contain some very constructive thought and indicate that some important changes in cars will occur in the next 10 years. Changing living and traffic conditions, especially in large cities, are making the automobile increasingly necessary for persons who live in the outskirts of the big communities, and the car of 1937 is certain to differ from present types. The field of speculation as to what it will be is a wide one, and a lively competition for the $100 award is anticipated.

MODERN AIR TRANSPORTATION DISCUSSED

Cleveland Section Holds Air-Transport Dinner and Talks about Air Travel

The subject of Air Travel as a Practical Means of Transport was well threshed-out at the meeting of the Cleveland Section that was held April 25. About 100 members and guests attended the special dinner in the ballroom of the Cleveland Hotel, and 150 persons were present at the technical session. The principal address was by L. B. Seymour, chief engineer of National Air Transport, Inc., Chicago.

After some of the representatives of the Section had presented their opinions regarding the public's attitude toward the present use of air-transport facilities, Mr. Seymour delivered his address and devoted special comment to the opinions that had been expressed. The assembled members and guests then indulged in a free-for-all discussion.

An illustrated account giving the main points made by Mr. Seymour will appear in the June issue of THE JOURNAL.

PACIFIC-COAST HIGHWAY-IMPROVEMENT

Northern California Section Discusses Traffic Influences on Highway Design

Traffic Requirements in Highway Design, and the Carquinez Strait Bridge and Its Economy in Reference to Automotive Transportation, are the titles of the two papers presented at the meeting of the Northern California Section that was held on April 14. The former paper was by C. C. Cottrell, manager of the highway bureau of the California State Automobile Association; the latter, by Prof. Charles Derleth, Jr., of the department of civil engineering, University of California, and also chief engineer of the bridge construction. Preceding the technical session, of which Edwin C. Wood was chairman, a dinner at the Commercial Club, San Francisco, was attended by numerous members and guests.

Mr. Cottrell said in part that efforts should be made to protect existing highways as well as to make highways of sufficiently heavier construction to withstand the increasing demand of traffic. He believes it necessary to increase the speed of present traffic and to "bank" the highway curves to make them safe at these higher vehicle-speeds. It was mentioned in this connection that an appeal is now before the State legislature to increase the permissible speed of vehicles from 35 to 40 m.p.h. The details of proper surfacing of highways were then presented.

Professor Derleth gave a profusely illustrated description of the construction of the Carquinez Strait bridge in all its various stages, including four reels of motion pictures illustrating the raising of the bridge spans. This bridge is a cantilever-type structure designed to provide highway and trolley-car connection between Crockett and Vallejo, Cal., tying together the high rocky bluffs on the north shore of Carquinez Strait, one of the eastern inlets of San Francisco Bay, with the flat lands on the south shore, and forming a direct highway between Berkeley and Sacramento, Cal. The main bridge crossing the Strait has two 500-ft. anchor-arms and two 1000-ft. spans each consisting of a suspended-span between two cantilever-arms, all symmetrically spaced about a tower-span, making a total length of 3350 ft. On the south shore is a curved-viaduct approach, 1130 ft. long. A total of 15,390 tons of structural steel was used in constructing the bridge and numerous seemingly insurmountable difficulties of construction were overcome successfully, the most notable being in connection with the building of the piers in deep water. The main span carries a 30-ft. roadway between the trusses, with trolley-car tracks in the center and a sidewalk on either side. The bridge affords a direct outlet to the north and east from Berkeley, in contrast to the former circuitous routes that skirted the Strait, the Bay and numerous inlets, and is a notable example of engineering achievement in the interest of highway development.

ENGINEERING AND PRODUCTION WORK

Indiana Section Considers Various Automotive Production Phases and Methods

Three papers dealing with production were presented at the meeting of the Indiana Section that was held April 14 at the Hotel Severin, Indianapolis, following a dinner attended by 101 members and guests. About 60 persons were included in the party that inspected the plant of the Marmon Motor Car Co. in the afternoon, and 225 were present at the technical session in the evening. Ralph R. Teetor was chairman.

In presenting his paper on the Relation of Engineering to Production, George H. Freers, assistant chief engineer of the Marmon Motor Car Co., said that to build motor-cars on a production basis means to him that a company should decide as to how many cars it will build per day; design, tool-up, and purchase material accordingly; and then build that predetermined number of cars each working day. He considers that the building of cars on a production basis does not mean, necessarily, the producing of a great number of cars.

The automotive engineer of today must, in Mr. Freers' opinion, be capable of designing, developing and producing. By producing Mr. Freers does not mean to infer that the engineer must literally produce, but that the engineer must know the elements of production so that his design can be manufactured inexpensively, accurately and in quantity.

In the case of a company which manufactures all its major units and purchases only the accessories, Mr. Freers said that the engineer of such a company has a real production problem to solve. In producing a new car, the first problem is the original design in the drafting room; the second, building the experimental cars and doing the development work; and the third, getting the car into production. Great care must be taken to see that the experimental drawings really become the production drawings that will be used later. The limits, tolerances and specifications must not only give the correct sizes and the like but they must also be of such a nature that the parts can be manufactured on a commercial basis. The experimental and development stage constitutes one of the difficult phases of the work and is virtually a check upon the work done in the engineering department proper. From the development stage to the production stage is where the engineering department has its most important work.

It is at this time that the experimental drawings are turned into production drawings and mistakes on production drawings are usually very expensive. The shop executives check all drawings before they are released for production.

When starting to build a new car, Mr. Freers said that the contact between the engineering department and the production department in the shop must necessarily be very close. The engineer's principal work is no longer chiefly that of an office position, as much of the engineer's time must be spent in the shop. Mistakes are made in the engineering department and in the manufacturing process; various parts are not up to specifications and sometimes substitution of materials must be made. Difficulties are also encountered that did not show up during the development work and for these reasons team-work between the shop and the engineering department is essential. Mr. Freers said that his company has reached the conclusion that the engineering department is just as much a shop division as it is an office division. In conclusion he emphasized that the engineering department's contact with the production department must be of a cooperative nature and not along the lines of criticism, and said also that the closer the contact and the better the cooperation are, the more nearly perfect the final results will be.

Modern Automobile Production

After outlining the early history of automobile production, W. K. Swigert, production manager for the Stutz Motor Car Co. of America, said that the function of a production planning-department should include plans for buildings, for routing materials, machine-shop layout, commercial and special tooling, assembly and inspection. He then differentiated between the practices in plants having small and those having large production-capacity, and sketched the methods that are used in each of the two types of plant.

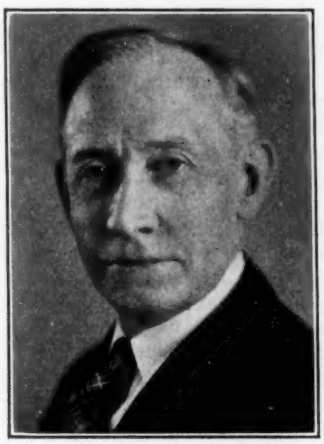
Chromium-Plating

In presenting his subject C. H. Humphries, chief engineer of the Metals Protection Corporation, Indianapolis, said in part that by chromium-plating is meant the deposition of chromium from a water solution of chromium salt by means of the electric current. Various plating solutions are in use and one of the problems connected with the subject is to pick out the best solution. Some of the uses to which chromium-plating has been applied in the automotive industry are head-lamps, spot-lights, cap nuts, fan shafts, crankshafts, valves, and valve-tappets. The advantages gained by such use are due to the hardness and to the smoothness of chromium and also to the fact that the coefficient of friction for polished chromium is much less than is the coefficient of friction of polished steel. This last factor has a tendency to reduce the lubrication requirements. Hence it is evident, the speaker said, that chromium-plating is useful as a protection against wear.

One of the properties of chromium which makes it suitable for the production of finely finished surfaces is that relatively thin coats of chromium will resist scratches. On brass, a plating of chromium 0.0003 in. thick is sufficient to prevent scratches. The thickness of the chromium-plating used on other parts varies usually from 0.0005 to 0.0010 in. Another advantageous feature is that chromium does not tarnish in the air, as does nickel, and neither is it affected by carbon dioxide in moisture. This feature makes it especially suitable for plating radiator shells.

In reference to the cost of chromium-plating, Mr. Humphries cited an example. Supposing that 1 lb. of chromium will cover 266 sq. ft. with a plating 0.0001 in. thick and that the chromium in the solution cost $3 per lb., this approximates a cost of 1 cent per sq. ft. If the specification calls for a greater thickness, such as 0.0005 in., the cost would be approximately 6 cents per sq. ft. on a coverage of say 53.5 sq. ft. Hence, the chromium-plating of one-sixth of this supposed surface would cost approximately 1 cent. It would then be more capable of resisting wear and there would be three or four times the thickness of chromium as compared with other platings. Chromium-plating is more difficult to accomplish than nickel-plating or copper-plating. In the average chromium solution unless particular care is taken the tendency is for the chromium to be deposited on some high spot or point and in such case there will be an adjacent recess in which no chromium is deposited. The chromium-plating solution has a higher electrical conductivity than do other plating-solutions and for that reason particular methods and particular efforts must be adopted to overcome these peculiarities. In conclusion, Mr. Humphries suggested that trouble in engines due to the deposition of carbon may possibly be lessened by chromium-plating the interior of cylinder-heads, provided the additional cost of such plating were not too great, as carbon has but a slight tendency to adhere to a highly polished surface and can be blown-off readily.

George H. Freers



W. K. Swigert

C. H. Humphries

R. R. Teetor

The Three Speakers and the Chairman at the Indiana Section Meeting

Major Points of the Discussion

Frederick S. Duesenberg, of the Duesenberg Motors Co., Indianapolis, cited the result of tests made by his company to determine the resistance to wear and to corrosion of chromium-plated parts, and this was favorable to the efficacy of chromium-plating. In his opinion, chromium-plating has great possibilities of application, and he suggested that the chromium-plating of head-lamp parts may be very advantageous. In reply to a query from E. F. Davis, of the Warner Gear Co., Muncie, Ind., Mr. Humphries replied that no great success has so far attended the attempts to apply chromium-plating to gears. He said further that attempts have been made to chromium-plate milling cutters and drills and that the reports vary as to whether this is successful. On drills and on lathe tools for use on aluminum, a thin film of chromium on the edge of a high-carbon-steel tool

gives satisfactory service and produces a fine finish. Presumably, aluminum does not stick to chromium as it does to steel. However, only when aluminum or brass are being machined has the chromium-plating of the tool-edges any great value. It was mentioned that the fumes from the vats in which chromium-plating is being done are dangerous, and that the vats should be covered with hoods. The chemical action produces a mist or spray because of the large quantities of hydrogen released. The chromic acid in these mist-particles attacks the membranes of the nose and throat.

Replying to a question by H. C. Kramer, of the Stutz Motor Car Co., in regard to the comparative wearing-qualities of the lapped cylinder-bore and the ground cylinder-bore, Mr. Freers said that the lapping process produces a smoother and brighter finish than does the grinding process, and that his company has obtained wearing-qualities just as good or perhaps better from the former process as it has from the latter. A concluding feature of the meeting was the exhibition of motion pictures of grinding operations and grinding-tools, furnished by the Norton Co., Worcester, Mass.

The officers of the Section who were elected for the coming year are George H. Freers, assistant chief engineer of the Marmon Motor Car Co., chairman; Ralph R. Teetor, chief engineer of the Perfect Circle Co., vice-chairman; Charles A. Trask, equipment efficiency engineer for the Rockwood Mfg. Co., treasurer, and Raymond F. Buckley, secretary. F. F. Chandler was elected as the representative on the Nominating Committee of the Society, and Raymond F. Buckley was elected as alternate.

MECHANICAL FEATURES OF LEAF SPRINGS

Detroit Section Told How Leaf Springs Act Under Conditions of Suspension

Underlying principles of leaf-spring design, with particular reference to the dynamic behavior of springs and to interleaf friction, were the outstanding points of the paper on Some Mechanical Features of Suspension Leaf-Springs, by Tore Franzen, S. P. Hess and Clark A. Tea, at the meeting of the Detroit Section that was held on April 21. The author is assistant chief engineer of the chassis-spring division of the Detroit Steel Products Co. Mr. Hess, chief engineer of the spring division of the same company, and Mr. Tea, collaborated with Mr. Franzen. The chairman of the technical session was W. R. Griswold, engineer in charge of analysis of design for the Packard Motor Car Co.

In reference to the main-plate stresses, Mr. Franzen said that the principal stresses in a leaf spring are those caused by bending and are transverse. Usually, these transverse stresses are determined by calculation but now, by using a strain gage that was developed recently, it is possible to measure such stresses directly. The two points of the gage are held against the surface that is being investigated and, as the skin of the metal is elongated or shortened, the movable point of the instrument actuates an indicator pointer through a 300 to 1 leverage. Each graduation on the dial corresponds to a stress of 4000 lb. per sq. in.

Since stresses constitute a principal factor in spring design, Mr. Franzen reviewed the fundamental theory of simple leaf-springs having a rectangular cross-section and then discussed the subject of interleaf friction. He outlined the research program that was adopted for the determination of interleaf friction and said that the important conclusion to be derived from the tests made is that graphite maintains a constant coefficient of friction between the leaves of a spring.

Dynamic tests of leaf springs, with particular emphasis placed on the correlation of static and dynamic friction to vibration qualities, were made. Mr. Franzen described these tests and the special machine on which they were made, citing also the data obtained. He then discussed the relation of number of leaves to damping effect, saying that a very important conclusion reached from the preceding tests expresses a definite mathematical relationship between number of spring leaves and number of periods required to damp a spring.

Points Brought Out in the Discussion

Answering a question, Mr. Franzen defined the "nip" of a spring as the force needed, expressed in pounds, to bring the plate or leaves of a spring together at two specified points. In reference to how well the stresses in a spring compare when calculated and when measured by the gage, he said that the latter values are practically an average between the high and the low values of the former method, if the "seat" is not considered. He mentioned in reply to another question that he had made no accurate measurement of the effect that lubrication of springs has on riding-quality.

Asked by F. C. Mock, research engineer for the Stromberg Motor Devices Co., whether the frictional absorption of rusty springs had been measured, Mr. Franzen replied that the surfaces he has dealt with remain smooth and that he knows little about the "top" rust. Questioned further by Mr. Mock as to measurements of frictional absorption of springs lubricated with ordinary lubricant at temperatures of 0 to −20 deg. fahr., Mr. Franzen answered that there is decidedly greater damping-effect at very low temperatures.

Some of the other points brought out by questions are that the actual frequency of a spring depends upon the deflection as calculated from the upper, or compressed portion, of the hysteresis curve; that is, the frequency depends upon the static deflection. As to the maximum allowable stress per square inch on the main leaf of a spring, Mr. Franzen said that main-plate stresses in a spring used in connection with a good shock-absorbing device can be high. He cited an instance of a static stress of 60,000 lb. per sq. in. in a front spring, whereas 45,000 lb. per sq. in. was considered high a few years ago, and said he knows of another instance in which the static stress was 80,000 lb. per sq. in. Ordinary static stresses are 50,000 to 55,000 lb. per sq. in. for front springs and 60,000 lb. per sq. in. for rear springs. Mr. Franzen said further that, in regard to keeping interleaf friction constant, a liberal usage of graphite grease is the most successful means yet found.

E. V. Rippingille, sales engineer of the Delco-Remy Corporation, said that in his experience the surfaces of spring leaves differ widely and that he finds it impossible to maintain any lubricant between the high points of contact. He suggested that what is needed is an "air-tight" spring, inferring that lubricant might then be forced in some manner to the dry points, and asked if any attempt has been made to coat the leaves of springs with any substance. Mr. Franzen replied that no such attempt has been made, saying also that tests made with thin oil between the leaves showed vastly different static-stress features that were not due to poor workmanship in making the spring.

INFLUENCES OF REGIONAL PLANNING

Tendencies and Effects on Traffic Control Studied by Pennsylvania Section

The subject presented at the meeting of the Pennsylvania Section that was held at Kugler's Restaurant on April 12 was Traffic Control and Direction and General District Planning. H. M. Lewis, executive engineer of the Regional Plan of New York and Its Environs, illustrated his address with lantern slides, and charts were used by Samuel P. Wetherill, Jr., president of the Regional Planning Federation of the Philadelphia Tri-State District, as an aid in illustrating the points he made. A dinner preceded the technical session.

Regarding the Tri-State District, Mr. Wetherill said in part that this is a great metropolitan area of more than 3000 sq. miles, bound together by common interests and problems but with its affairs administered by 357 different political subdivisions, exclusive of school districts. Here, in portions of 3 States, are all or parts of 14 counties, 211 townships and 129 incorporated cities and boroughs classi-

(Continued on p. 565)

OPERATION AND MAINTENANCE

SUBCOMMITTEE PERSONNEL ANNOUNCED

Operation and Maintenance Committee Members Grouped for Effective Work

The personnel of the Operation and Maintenance Committee of the Society was listed on p. 404 of the March issue of THE JOURNAL. The members of the Committee have been appointed to the following Subcommittees to carry on the work more effectively.

SUBCOMMITTEE ON ACCOUNTING

R. E. Plimpton, *Chairman*	*Bus Transportation*
F. K. Glynn	American Telephone & Telegraph Co.
W. R. Gordon	Pierce-Arrow Motor Car Co.
M. W. Glover	West Penn Railways
G. R. Gwynne	Continental Oil Co.
M. C. Horine	International Motor Co.
F. C. Horner	General Motors Corporation
W. P. Kennedy	Kennedy Engineering Corporation
E. E. LaSchum	American Railway Express Co.
J. H. Lyons	City Transportation Co.
J. F. Winchester	Standard Oil Co. of New Jersey

SUBCOMMITTEE ON EDUCATION

E. Favary, *Chairman*	Moreland Motor Truck Co.
F. K. Glynn	American Telephone & Telegraph Co.
C. M. Manly	New York City
L. H. Palmer	Fifth Ave. Coach Co.
J. F. Winchester	Standard Oil Co. of New Jersey

SUBCOMMITTEE ON MECHANICAL-INFORMATION SHEETS

J. F. Winchester, *Chairman*	Standard Oil Co. of New Jersey
M. C. Horine	International Motor Co.
L. V. Newton	Pure Oil Co.
T. L. Preble	White Motor Co.
E. C. Wood	Pacific Gas & Electric Co.

SUBCOMMITTEE ON MOTOR-VEHICLE REGULATIONS

F. J. Scarr, *Chairman*	Pennsylvania Railroad
F. D. Howell	Motor Transit Co.
Adrian Hughes, Jr.	United Railways & Electric Co. of Baltimore
J. F. McMahon	Yellow Taxi Corporation
H. V. Middleworth	Consolidated Gas Co. of New York
R. E. Plimpton	*Bus Transportation*
G. W. Reimann	American Railway Express Co.

SUBCOMMITTEE ON NOMENCLATURE

F. K. Glynn, *Chairman*	American Telephone & Telegraph Co.
D. L. Bacon	New York, New Haven & Hartford Railroad
Eugene Power	Union Oil Co. of California

WEST-COAST SUBCOMMITTEE

E. C. Wood, *Chairman*	Pacific Gas & Electric Co.
E. Favary	Moreland Motor Truck Co.
G. R. Gwynne	Continental Oil Co.
F. D. Howell	Motor Transit Co.
J. H. Lyons	City Transportation Co.
Eugene Power	Union Oil Co. of California

Chairman R. E. Plimpton, of the Operation and Maintenance Committee, has suggested programs as outlined below for the Subcommittees formed when the general Committee was first organized last year. These suggestions have been sent to each member and the Chairman of each Subcommittee has been asked to direct the work of his Subcommittee.

The West-Coast Subcommittee will give the Far-West members of the general Committee an opportunity to work together directly and with the rest of the Committee by correspondence. It is planned to have this Subcommittee prepare a general report on motor-vehicle-fleet operation and maintenance engineering as practised on the Pacific Coast, dealing with mass operation and maintenance as two distinct phases of the subject. This report will be presented by Chairman E. C. Wood, who has been invited to represent his Subcommittee at the Annual Transportation and Service Meeting that will probably be held in Chicago in November.

The general program for the Accounting and the Nomenclature Subcommittees has been outlined above. The latter will also prepare such other nomenclature and definitions than those relating to accounting as may seem desirable and useful.

The Motor-Vehicle-Regulation Subcommittee's program will include the collecting and reviewing of rules and regulations pertaining to operation in various States, especially those governing large fleet operators. The particular topic so far discussed is the present practice required by law in various States for the registration of engine numbers and the troubles that result therefrom in maintenance where complete engine changes are made in a chassis. Undoubtedly this Subcommittee can also render valuable service to States by reviewing proposed vehicular regulations and offering suggestions regarding requirements and enforcement.

The Subcommittee on Education has been asked to prepare its own program, although it has been suggested that it can cooperate with the other Subcommittees in making the results of their work of more value to operators. Probably much of its work will relate also to spreading information regarding the Operation and Maintenance Committee among operators and companies, showing particularly how and where the Society can be of valuable assistance to them.

COMMITTEE MEMBERS SERVING ON OTHER COMMITTEES OF THE SOCIETY

Members of the general Committee are also serving this year on the Meetings, Membership, Publication, Research, and Sections Committees of the Society and will support the interests of the operators in these branches of the Society's work. The list of these representatives is as follows:

MEETINGS COMMITTEE

J. F. Winchester	Standard Oil Co. of New Jersey

MEMBERSHIP COMMITTEE

F. K. Glynn	American Telephone & Telegraph Co.

PUBLICATION COMMITTEE

E. E. LaSchum	American Railway Express Co.

RESEARCH COMMITTEE

A. W. Herrington — City of Washington

SECTIONS COMMITTEE

E. C. Wood — Pacific Gas & Electric Co.

CLASSIFICATION OF OPERATING COSTS

Operation and Maintenance Committee Collecting Data on Existing Systems

With the personnel and subcommittee organization of the Operation and Maintenance Committee of the Society virtually completed, the Accounting Subcommittee held its first meeting in New York City on March 28 to decide upon a program. For some time suggestions have been offered, amounting practically to requests, that a uniform basis for comparing motor-vehicle-fleet operating costs be studied and formulated. It was felt that in developing such a classification, motor-truck, taxicab and motorcoach operation should be studied as they are more or less related in a number of ways. Those who attended the meeting felt that the fundamental requirements should first be determined for the result desired and then the best procedure developed to obtain that result. The Subcommittee therefore decided to collect as many data as are available in the classification of motor-vehicle accounts as developed by other associations and large operating companies and to select from these data all items that it is believed should be included in a recommendation.

It may be feasible later to collect actual costs and compare them under the Committee classification, although it is felt that the comparison of such costs would be too speculative, because of varying conditions, to make them of any value as part of the Committee's work. It is felt very strongly, however, that, with a uniform classification, direct comparison of costs can be made by companies operating the same classes of vehicle under approximately the same conditions and that from such comparisons relatively weak spots in their operation and maintenance can be detected and remedied.

One of the factors that will be important in the work of the Subcommittee is a clear understanding of the terms used in the classification and just what each will include. Largely for this purpose, a Nomenclature Subcommittee was organized this year to cooperate with the Accounting Subcommittee by defining the exact scope of each term of the general classification that the latter will outline from the mass of data being collected. Without a clear understanding of all its terms, the classification would be of too limited use and would lead to erroneous comparisons of costs.

Those present at the meeting in New York City on March 28 were R. E. Plimpton, of *Bus Transportation*, chairman; D. L. Bacon, of the New York, New Haven & Hartford Railroad; A. W. Einstein, of the Retail Delivery Association; F. K. Glynn, of the American Telephone & Telegraph Co.; M. C. Horine, of the International Motor Co.; F. C. Horner, of the General Motors Corporation; W. P. Kennedy. of the Kennedy Engineering Corporation; H. V. Middleworth, of the Consolidated Gas Co.; T. L. Preble, of the White Motor Co.; C. W. Stocks, of *Bus Transportation;* and C. F. Clarkson, general manager, and R. S. Burnett, manager of the Standards Department, of the Society of Automotive Engineers.

OIL-TANK TYPE MOTOR-TRUCKS

Recommended Construction and Operation Practice for Fire Prevention

As stated by H. E. Newell, engineer of the National Board of Fire Underwriters, at a meeting of the American Petroleum Institute, during the last 7 years fire chiefs or other municipal officials have requested data on oil-tank-truck safeguards for ordinance purposes. These requests were usually brought about by fires or other accidents involving tank-trucks. In 1924 this subject was placed on the program of the Conference Committee of the National Fire Protection Association Committee on Flammable Liquids for the purpose of compiling data and framing suitable regulations. The membership of this Conference Committee included representatives from the oil industry, manufacturers of tank-trucks and the Society of Automotive Engineers. Aid was also secured from the Bureau of Standards. At a meeting of the Conference Committee held in Chicago last year practically all of the larger oil-companies and tank-truck manufacturers were represented. At one of the early conferences it was decided to designate the final requirements as "Recommended Good Practice" rather than call them regulations or arrange them in ordinance form. The final draft will be submitted for tentative adoption by the National Fire Protection Association at the Congress Hotel in Chicago this month.

The following table indicates the details of 61 fires that occurred during the period 1917 to 1925 inclusive. It is not the record of all tank-truck fires that occurred during that period, but it may, in Mr. Newell's opinion, be considered as a record of the outstanding oil-tank-truck fires during this 9-year period.

DATA ON OIL-TANK MOTOR-TRUCK FIRES

Fire Causes	Number of Fires Due to Each Cause	Casualties Injured	Casualties Killed	Extent of Loss	Remarks
Static Electricity and Stray Currents	10	41	9	$254,466	Loss not stated in 2 cases
Unknown	9	25	11	94,215	Loss not stated in 4 cases
Engine Operated during Filling	8	1	—	157,500	Loss not stated in 5 cases
Struck by Locomotive	6	2	5	27,915	Loss not stated in 2 cases
Drivers' and Mechanics' Matches	4	1	—	———	Loss not stated
Collision with Automobiles	3	—	—	———	Loss not stated
Improper Filling Operations	3	—	1	600	Loss not stated in 2 cases
Compartment Overflowed	2	—	—	6,000	
Collision with Fill Pipe	2	—	—	7,000	Loss not stated in 1 case
Vapor Ignited by Heat from Manifold or Brakes	2	—	—	4,700	
Vapor Ignited by Sparks from Bucket	2	—	—	4,000	Loss not stated in 1 case
Leaky Valves	1	—	—	———	Loss not stated
Vapor Ignited by Locomotive	1	—	—	———	Loss not stated
Vapor Ignited by Lantern	1	—	—	———	Loss not stated
Pump Engine Back-fired	1	—	—	6,000	
Leaky Compartment	1	—	—	400	
Short-Circuit in Truck Wiring	1	—	—	1,800	
Vapor Ignited by Exhaust	1	—	—	———	Loss not stated
Truck Driven over Embankment	1	—	—	———	Loss not stated
Gasoline Used for Cleaning Truck	1	1	—	———	Loss not stated
Draw-Off Valve Left Open	1	—	—	13,000	
	61	71	26	$577,596	

It will be noted that static electricity and stray currents were the causes of the greatest number of fires, and it is argued that the oil industry should initiate such research and necessary experimental work as to determine beyond all question the exact extent of static-electricity possibilities and means of abatement that will not be subject to serious criticism.

Ten of the other causes might very properly be grouped and redesignated "Carelessness." They constitute approximately 40 per cent of the total number of causes. As this

table indicates solely the initial cause of trouble, it seems proper to state that, in those cases where collision other than with locomotives occurred, the destruction of draw-off valves and subsequent escape of oil was due to the lack of suitable bumpers or other proper safeguards.

Probably the most important contributing cause of tank-truck fires, Mr. Newell states, is that relating to vents. While the type of vent usually employed, viz., that known as the $\frac{3}{4}$-in. vent, but actually having only a $\frac{3}{8}$-in. vent-opening, is sufficient to take care of air displacements due to filling operations, it does not have sufficient venting-capacity safely to relieve internal pressures resulting from exposure fires.

From the standpoint of the life hazard, it will be observed that 39 of the fires entailed a life loss of 26 and injuries to 71 persons. Thirty-one of these fires involved property damage to the extent of $577,596. In many cases the records did not indicate personal injuries or loss of life or extent of property damage, so that it is safe to assume that more accurate records would indicate additional losses in these respects.

It seems reasonable to believe that any material or process possessing inherent fire-hazards should be regulated in such a manner as to reduce them to the minimum. Such regulations by municipalities are only justified when industry fails or shows no inclination to regulate itself. With traffic conditions in our large cities getting almost beyond adequate control, the tendency to regulate wherever possible the transportation of hazardous commodities will increase.

Relative Data

Any statement of the losses resulting from fires in any branch of industry does not give a true picture of the degree of hazard involved, without data showing the amount or value of the commodity handled. The table given above shows losses amounting to $577,596 from oil-tank-truck fires during the 9-year period 1917-1925. During this period probably 50,000,000,000 gal. of petroleum oils has been handled by tank wagons; the domestic consumption of gasoline alone amounted to about 47,000,000,000 gal. for this period, most of which was handled by tank-truck before it reached the consumer.

Using 50,000,000,000 gal. of products as a basis, the loss quoted above amounts to only 0.0012 cent per gal. Or, from another point of view, at 1500 gal. per truck, 50,000,000,000 gal. of oil represents 30,000,000 truck-loads or 1 fire for each 500,000 loads delivered.

These relationships are pointed out, not to minimize the importance of any activity which aims to decrease the hazard in handling petroleum products, but merely to make sure that an incorrect impression regarding the magnitude of this hazard is not created.

Cooperation by This Society

At the time the proposed regulations were being formulated by the Committee of the National Fire Protection Association, those items that were of more direct interest to the motor-truck chassis manufacturers were referred to the Motor Truck Division of the Standards Committee for study. The recommendations of the Division as representing the motor-truck manufacturers rather than the Society officially, were printed on p. 544 of the December 1925 issue of The Journal, and are included in the current issue of the National Fire Protection Association Committee's report with the exception that in the second sentence of the paragraph relating to Fuel Tanks the word "fire" before the word "hazards" has been omitted; in the first sentence of the paragraph on Fuel Feed System and the paragraph on Carbureters, the word "inherent" before "fire hazard" has been omitted. Under the section for Electrical Equipment, Construction and Installation, the specification that "electric lighting only shall be used" has been changed to read that "electric lighting only shall be used for tail lights." The following has been added to this section:

> Where gas headlights are used they shall be extinguished during loading and unloading operations. Gas head-lights or gas lanterns shall be provided with reliable means for mechanical ignition. The use of oil lanterns and matches shall be prohibited.

MERCHANDISING MOTOR-TRUCK OPERATION

Engineering Management Brings Success in Operation, Maintenance and Service

The paper by C. S. Lyon on the operation and maintenance of motor-trucks in heavy haulage is printed in this issue of The Journal p. 582. Unusual interest attaches to the use of a dynamometer and its value for testing overhauled engines, and engines in new equipment that do not perform properly. The author and also the superintendent of automotive equipment for another large company discuss and attest to the saving of truck time and labor in the repair-shop that is effected by use of the dynamometer.

Experimental duralumin van bodies for use on semi-trailers are a new development of great promise. They weigh only about half as much as conventional wood-and-steel bodies of the same dimensions. Although the first cost of the duralumin body was considerably more than the cost of the usual van body of equal size, subsequent bodies should not cost much more. The reduction in dead-weight that can produce no revenue is of prime importance.

The suspension of armored cabs on ball-bearing hangers, whereby the racking of the cabs and breakage of the chassis frames is avoided, and the cooling of the cabs in warm weather by means of blowers, are also of interest.

Emphasis is placed in the paper on the need for businesslike methods by an operating company, and a practical example of economy in the location and construction of garages is given. The author is by engineering training and practical experience well qualified to write on the subject with which the paper deals.

MOTORCOACH GARAGE SPECIFICATIONS

National Fire Protection Association Committee Studying Garage Construction

Regulations for construction and operation of motorcoach garages have been reported by the Garage Committee of the National Fire Protection Association, of which H. E. Newell is chairman. John Stilwell represents the Society on the Committee, and R. E. Plimpton, chairman of the Society's Operation and Maintenance Committee, is also a member. Proposed regulations which limit open areas in garages to 20,000 sq. ft. and contain what are considered drastic requirements for heating and ventilating, will probably be presented as a progress report at the annual meeting of the National Fire Protection Association to be held in Chicago, May 9 to 12 inclusive.

The purpose of the proposed regulations is to provide a code to serve as a basis for insurance rates on future constructions, there being no such code at the present time for garages operating primarily for housing motorcoaches. The following principal parts of the proposed regulations that it is thought are of particular interest in the motor-vehicle field are taken from the complete draft of the report recently issued by Mr. Newell's Committee.

Construction

Section 1.—Heights

(a) Bus garages shall preferably be restricted to one story in height, without cellars, basements or other open spaces below the floor.

(b) In the case of one-story peaked-roof bus garages, height of walls above floor shall not exceed 25 ft. at eave lines or 30 ft. at peak of roof, except that in sprinkled garages having roof-truss spans over 100 ft. a maximum height of 35 ft. at peak of roof

shall be allowed. Draft curtains are installed extending from the roof to within 25 ft. of the floor, enclosing pocket areas of not over 5000 sq. ft. each. No story of any bus garage above the first story shall exceed in height 20 ft. for single-deck and 25 ft. for double-deck buses.

SECTION 2.—AREAS

In every bus garage the maximum area of any floor between fire-walls or exterior walls, either without or with a standard equipment of automatic sprinklers, shall be as provided in the following tables, unless subdivided by non-bearing fire-partitions.

(*a*) Height, Stories	Street Frontage	Area, Sq. Ft. Unsprinkled	Sprinkled
1	1	8,000	16,000
1	2 or more	10,000	20,000
2	1	6,000	12,000
2	2 or more	7,500	15,000

(*b*) The area limitations of the following table also assume standard enclosures for all vertical openings with openings therein protected by Class-B fire-doors.

	Height		
Frontage	3 Stories	4 Stories	5 Stories
1 Street	10,000 sq. ft.	8,000 sq. ft.	6,000 sq. ft.
2 or more Streets	12,000 sq. ft.	9,600 sq. ft.	7,500 sq. ft.

(*c*) Any of the foregoing area limitations may be increased 50 per cent, when further subdivided by fire partitions, provided that no such further subdivision exceeds 75 per cent of the maximum area prescribed by Sections 2(*a*) and (*b*).

(*d*) Any two-story bus-garage in which all vertical openings are enclosed in a standard manner and employing Class-B fire-doors at openings therein, and which has at least two street-frontages, may have the areas prescribed in Section 2(*a*) increased 33⅓ per cent when each story is provided with bus entrance direct from street.

SECTION 9.—WALL OPENINGS

(*a*) Openings in division walls or fire partitions separating bus-storage sections shall be restricted to one of dimensions not exceeding 180 sq. ft. for every 100 ft. or major portion thereof of such wall or partition length. Where walls are less than 100 ft. in length, one such opening shall be permitted. In addition to the above openings for buses, openings of dimensions not exceeding 38 sq. ft. shall be permitted.

SECTION 10.—PROTECTION OF VERTICAL OPENINGS

All floor-openings, such as shafts containing stairways, elevators, hoistways, chutes, ventilating ducts or similar vertical openings in bus garages of other than mill construction, shall be continuously enclosed with walls or partitions as required by the National Board Building Code. In the case of mill construction, stairways and elevator shafts shall be enclosed as required by the National Board Building Code.

SECTION 16.—VENTILATION

(*a*) *Car-Storage Rooms*

(*a*-1) A system of natural ventilation without mechanical means of circulating air will be permitted only where it is possible to maintain open windows at all times and uniformly distributed in two opposite outside walls. Total area of open windows in all walls to be at least 5 per cent of floor area.

(*a*-2) Where it is impracticable to operate a system of natural ventilation continuously, ... it will be necessary to operate a mechanical system for supplying fresh air to the room. This system shall supply at least 2 cu. ft. of air per min. for each square foot of floor area. This air is to be introduced uniformly into the occupied area through openings spaced not over 75 ft. apart and not less than 6 ft. above the floor, the incoming air to be directed horizontally in all directions. Recirculation of air through the ventilating system is prohibited.

(*a*-3) Where it is impracticable to operate a system of natural ventilation as described in paragraph (*a*-1), a mechanical system will be required, for removing the foul air, gases and the like. This system will consist of vent openings placed not over 50 ft. apart, and within 24 in. of the floor. These openings are to be connected, either directly, or by incombustible ducts or flues, to one or more spark-proof exhaust-fans capable of drawing through the system and delivering to the atmosphere the volume of air specified in paragraph (*a*-2).

(*b*)—*Car-Repair Room*

(*b*-1) Repair rooms in which internal-combustion engines are operated under power while stationary shall have fresh air supplied by a system of mechanical ventilation as specified in paragraph (*a*-2).

(*b*-2) Repair-rooms in which internal-combustion engines are operated under power while stationary shall have the exhaust gases removed by either of two methods.

> *Gravity Method.*—. . . . the engine will discharge direct to outdoors through a straight duct or pipe of incombustible material . . . .
>
> *Forced Ventilation Method.*—The exhaust gases shall be removed by one or more spark-proof exhaust-fans having their inlets connected to a duct system constructed of incombustible material.

Beneath each car, in which an engine is operated, shall be located an air-intake opening connecting into the duct system. Each intake-opening is to have at least 1 sq. ft. free area. A deflector hood and flexible tube of incombustible material shall be used to direct the exhaust gases from each engine exhaust-pipe into the corresponding air-intake opening to the duct system. The exhaust-fans are to be capable of drawing through the above described duct system and discharging to the atmosphere outdoors, not less than 1000 cu. ft. of air per min. from beneath each car in which an engine is operated.

SECTION 19.—REPAIRS

(*a*) Repairs on operating floors of bus garages shall be limited to inspections and replacement of parts and repairs incident thereto.

(*b*) General overhauling of the bus as a whole shall be restricted to a repair-shop cut off from the operating section of the garage by a fire-resistive partition.

PROTECTION

SECTION 24.—AUTOMATIC SPRINKLERS

Every one and two-story bus-garage exceeding the unsprinkled area limitations specified in Section 2 (*a*) and (*c*) and every bus-garage exceeding two stories in height shall be equipped throughout with a standard system of automatic sprinklers.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S.A.E. Standards Committee and other standards activities are reviewed herein

NEW MOTORCOACH-BATTERY STANDARD

Subdivision Appointed to Consider Specifications for New Types and Sizes

Because of the desire of many motorcoach builders to use two 6-volt batteries in place of one 12-volt unit, to provide greater ease of handling, the demand for batteries for this type of installation has greatly increased. At the request of one battery manufacturer, a survey of motorcoach builders and battery manufacturers was made to determine the attitude toward the adoption by the Society of specifications recommending this type of installation.

The results of the survey show great interest in the use of two units, the main advantage being that of reduction in weight, so desirable from installation and replacement viewpoints. The subject was thoroughly discussed at the Electrical Equipment Division meeting on April 1, which was attended by representatives of the battery manufacturers.

The use of 6-volt lamps to prolong lamp life was mentioned as influencing the use of two units because of the ease of tapping for the lower voltage. The inadequacy of motorcoach lighting systems has forced operators to seek more illumination, which in turn has required greater capacity in batteries. The resultant development of batteries with ¼-in. plates has been attended by a corresponding increase in weight, making the 12-volt unit particularly heavy, and has necessitated the development of a 6-volt battery with the thicker plates. It was suggested that, inasmuch as there are no existing S.A.E. Standards to cover this type of battery, some such specifications be drawn up.

As a result a Subdivision, whose personnel is made up of representatives of battery and of motorcoach manufacturers, has been named to develop new motorcoach-battery specifications for ¼-in. plate batteries and recommendations covering the use of two 6-volt battery units to replace one 12-volt unit.

SHEET STEEL DIMENSIONS AND TESTS

Methods of Testing and Designating Thickness To Be Proposed by Subdivision

The Subdivision on Sheet Steel of the Iron and Steel Division submitted a report on Sheet-Steel Dimensions and Sheet-Steel Tests for discussion at the last Division meeting which was held in Detroit on March 29.

Because of the several gages now in use for measuring sheet-steel thickness and the use of decimals by some companies to designate thickness when purchasing sheet steel, it is considered advisable that the Society approve a definite method of expressing sheet-steel thickness. A summary compiled from answers to a questionnaire sent to manufacturers and consumers of sheet steel indicated a preference for the use of decimals but, because of the great variation in the several kinds of sheet steel and the different methods of measuring used, it was decided to investigate the matter further, taking into consideration the work being done along similar lines by a committee of the American Sheet Steel Manufacturers.

The summary referred to above revealed little use of any standard method of testing sheet steel. The Subdivision has been investigating the matter of recommending standard tests for sheet steel, but it is felt that, before any specifications for such tests could be formulated, some method of testing should be approved by the Society.

While it was found that the most general test in use consists only in determining whether steel would work satisfactorily in the tools for which it was purchased, the Subdivision recommended approval of the Olsen method of testing, as this was found to be the most frequently used method in the relatively few cases where actual tests are made.

Action by the Division on this recommendation was deferred. The Subdivision has been requested to prepare a questionnaire to be sent to members of the Division and to sheet-steel manufacturers and users to obtain further information on which to base a conclusion.

PAPER ON PHYSICAL-PROPERTY CHARTS

New Method of Determining Curves for S.A.E. Steel 6130 To Be Described

The Chairman of the Subdivision on Physical-Property Charts presented to the Iron and Steel Division meeting on March 29 a report indicating the progress made in the development of physical-property charts for S.A.E. Steel 6130. The curves were determined by a method hitherto unused and because of this fact it was decided to make no definite recommendation for the approval of the charts until after some publicity had been given to the method.

A joint paper on the subject will be prepared by E. J. Janitsky, of the Illinois Steel Co., and H. T. Chandler, of the Vanadium Corporation of America, and presented at a steel session of the Production Meeting in September. The paper will also be published in THE JOURNAL.

While the basic data for the curves for 6130 Steel were obtained from over 30 laboratories cooperating in a special test of this steel, it is believed that sufficient data can be had for other S.A.E. Steels from routine-test results of various consumers and fabricators of steel.

HIGH-MANGANESE STEEL SPECIFICATIONS

Subdivision to Determine the Advisability of Adopting New Standards

The increasing use of high-manganese steel for automatic screw-machine work and other similar parts, and the demand for adoption by the Society of specifications for such a type of steel has resulted in the appointment of a Subdivision of the Iron and Steel Division to investigate the advisability of recommending the approval of specifications for this class of steel.

It was indicated in the discussion at the Division meeting on March 29 that the use of a high-manganese steel enables the designer to reduce the cost of parts without sacrificing quality. It should be understood, however, that such a steel will not replace Bessemer screw-stock, and that the approval of high-manganese steels by the Society will not constitute duplication.

The following Subdivision was appointed by Chairman

Watson to study the situation and make such recommendations as it deems advisable:

R. B. Schenck, Chairman	Buick Motor Co.
H. W. Graham	Jones & Laughlin Steel Corporation
W. G. Hildorf	Reo Motor Car Co.
W. R. Shimer	Bethlehem Steel Co.
E. W. Upham	Chrysler Corporation

WINDSHIELD-CLEANER MOUNTINGS

Standardization of Dimensions for Various Types under Consideration

In response to requests that some action be taken looking toward the standardization of windshield-cleaner mounting-dimensions, a Subdivision of the Parts and Fittings Division, under the chairmanship of F. G. Whittington, of the Stewart-Warner Speedometer Corporation, has been appointed to make a study of existing practices and, if feasible, to develop specifications for mounting dimensions for the various types of cleaner now in use.

Requests sent to manufacturers of these devices have elicited considerable information and interest in this work, and, although there is some question as to what extent such standardization can be carried, it is generally felt that the principal mounting dimensions can be covered.

OIL, GREASE AND LUBRICATOR-CUPS

Revisions and Additions to Present Specifications Being Considered

The Society recently received an inquiry from the United States Army as to what work was being done with reference to the standardization of oil, grease and lubricator-cup threads.

The Parts and Fittings Division has considered revising the existing S.A.E. Specifications in this connection. Inasmuch as the specifications were adopted several years ago, a Subdivision was named to study the subject. Standardization of thread sizes and lengths and hexagon-shank dimensions will be discussed.

The Subdivision will also consider the shank size of press-fit lubrication fittings with a view to determining dimensional specifications.

BLACK BAKING-ENAMEL TEST-PANELS

Inspection by Paints, Varnishes and Enamels Subdivision After Year's Exposure

About 3 years ago a Subdivision on Paints, Varnishes and Enamels was organized under the Passenger-Car Division of the Standards Committee to study the possibility of formulating standard specifications for the testing of paints, varnishes and enamels. Study of the subject indicated that it would be a very difficult one at best and it was decided to confine the work for the time being to black baking-enamel to avoid at once getting into the problem of working with materials containing color pigments.

After preliminary tests by members of the Subdivision, the results of which proved disappointing, specifications for the preparation of a large number of exposure-test panels and for the test procedure were adopted. Panels for the tests included three bakes of three grades of four makes of enamel prepared by nine members of the Subdivision, making a total of 324 panels on test. All the enamels used were given a code letter so that no member of the Subdivision could identify the various makes of enamel. These were placed on exposure test last June at the plant of the Pittsburgh Plate Glass Co. in Detroit, subsequent inspections being made by the Subdivision on July 15 and Sept. 16 of last year and March 31 of this year.

The solvent used in connection with the exposure tests was furnished by the Sherwin-Williams Co. to all members of the Subdivision in order to make a check-test on the solvents used by each tester in reducing the enamels to the proper consistency for flowing on the panels.

At the meeting of the Subdivision on March 31 it was felt that nothing could be gained by further exposure of the panels and the inspections made on that day were, therefore, final. The data obtained from that and previous inspections are being rearranged and summarized by the Standards Department of the Society preparatory to sending them to all members of the Subdivision for final study to determine whether it would be possible to set up a standard laboratory-test for black baking-enamels to take the place of the tedious and more or less unreliable method of testing by exposure. Further review of the Subdivision's work on this subject will be printed in a later issue of THE JOURNAL.

Those in attendance at the meeting in Detroit on March 31 were: W. H. Graves, chairman, Packard Motor Car Co.; V. C. Bidlack, O'Brien Varnish Co.; P. R. Croll, Pittsburgh Plate Glass Co.; E. C. Fries, Studebaker Corporation of America; J. O. Hasson, Sherwin-Williams Co.; W. H. Hogben, Pittsburgh Plate Glass Co.; J. A. Huetter, Packard Motor Car Co.; J. J. Kroha, O'Brien Varnish Co.; R. J. Moore, Pratt & Lambert, Inc.; H. C. Mougey, General Motors Corporation; M. J. Pearce, Glidden Co.; E. E. Ware, Sherwin-Williams Co.; R. J. Wirshing, General Motors Corporation Research Laboratories; G. F. Yott, Cadillac Motor Car Co.; and Standards Manager R. S. Burnett.

BUSHINGS FOR STEERING-COLUMNS

Standardization of Oilless Type for This Application To Be Undertaken

As stated in the Parts and Fittings Division report to the Standards Committee, which is printed on p. 557, it has been recommended that the present S.A.E. Specification for Oilless Bushings be cancelled.

In reply to questions raised at the Parts and Fittings Division meeting on March 31, Robert Thuner, of the O. & S. Bearing Co., stated that although it is not feasible to attempt standardization of oilless bushings for all locations, there is a need for standardization of steering-column bushings. A few sizes will take care of all requirements and it is believed that the information which will be provided by the adoption of such a standard will be of considerable value to engineers in designing steering-columns.

A Subdivision under the chairmanship of R. V. Hutchinson, of the Olds Motor Works, has been appointed to carry on this work.

Detroit Production Management Meeting

Control of Inventory and Production Costs and Other Problems Considered at 3-Days' Joint Sessions

Much good grist and very little chaff went through the mill in the 3 days' grinding at the production management meeting in Detroit on April 27, 28 and 29. The meeting was promoted by the Production Executives' Division of the American Management Association with the cooperation of the Management Division of the American Society of Mechanical Engineers and the Detroit Section of the Society of Automotive Engineers. Eight sessions were held and were attended by from 100 to 150 members at each session. Because it was a management meeting, most of the papers and discussion dealt with the problems of management of production rather than with production engineering and processes. Avoidance of waste through control of inventory, the planning and control of work in process, the reduction of costs, and the control of avoidable expenditures under abnormal conditions were the principal subjects treated by the various speakers. Discussion was animated and brought out many valuable ideas.

It developed that management is striving to realize an ideal, as regards inventory investment in raw materials, materials in process and finished product, to reduce carrying charges. Two automobile companies have carried this movement to the extreme of dispensing altogether with stockrooms and have operated on this basis successfully for periods of 2 and 3 years. There seemed to be general acceptance of the idea that excess should be pushed back to the raw materials and that the inventory of process and finished product should be maintained at the minimum consistent with uninterrupted production and sales. The effect this has on the vendor, or supplier, and how he can deal with his own problem were discussed extensively, and out of the talk evolved the expression of opinion that he should be satisfied if given reasonable notice of increases or decreases in delivery orders, and should himself regulate his production and receipts of raw materials accordingly.

Systems for planning and regulating production were given in detail, starting with the sales forecast and following down through the production authorization, purchasing orders, operation, time studies, production schedule and so on. Methods of controlling avoidable expenditures in periods of increasing and decreasing production and of change of design proved of practical interest. A summary of a report by a committee of the American Engineering Council, which is to be published in about 1 month, showed that in a number of large industries large increases in the rate of production per man-hour have been accompanied by decreases in both the frequency of accidents and the severity of accidents to workers. Another speaker told how a system of training apprentices and old employes has resulted in lowered production-costs.

J. H. Hunt, president of the Society, presided at a dinner the night of April 28 at which one of the two speakers gave a description of industrial conditions in Russia that revealed a situation very different from the general impression gained from newspaper reports. The other speaker presented an admirable summation of the effects the engineer had on production and on national prosperity.

WHERE TO EXERCISE EXPENSE CONTROL

Location of Causes of Unnecessary Cost and How To Correct Them

The opening session during the forenoon of April 27 was devoted to the problem of locating and controlling the causes of unnecessary expenditures in production. Oscar Grothe, vice-president of the White Sewing Machine Co., presented the first paper. In the unavoidable absence of Wallace Clark, consulting management engineer, the paper prepared by him was read by W. J. Donald, directing manager of the American Management Association.

After decision has been made to manufacture and market an article, said Mr. Grothe, one of the first points is to study location for a factory, as to closeness to raw materials, labor, transportation and main markets, but having also in mind that a change in conditions may come; hence the buildings must not be of such a character that they cannot be

used for other purposes. The amount and layout of the floor area and equipment should be studied carefully. If too much single-purpose equipment is installed it may retard progress later. It seems better, as a rule, to have standard machinery with special jigs and fixtures so that the machinery will not become obsolete. It has been found, also, he continued, that it is not advisable to equip for peak load but for average production, and to find other companies with excess capacity to take care of extra production until this builds up to a steady load.

Questions to consider with regard to materials are: At what point in manufacture to have reserves for making the manufacturing process most flexible? When it may be necessary to build up stock and how much? And how long ahead is a schedule required for the suppliers? If they are required to carry too large stocks the cost of the materials is increased, but careful cooperation with suppliers reduces cost to them and to the purchaser and results in prompt deliveries, a minimum inventory, and considerable reduction in floor area required. All these items have a bearing on the main factors of cost, which are interest, taxes, insurance, depreciation, maintenance, heat and light.

Careful analysis usually shows that it is possible to consolidate departments, especially in the accounting and office end, and thus avoid duplication of records. Another important point in cost control is the holding of regular meetings of all departments so that each may be familiar with the cause and effect of transactions in all departments. This often results in reduction in the number of models, simplification and elimination of unnecessary records, and assists in setting up intelligent sales programs.

Can Save Most on Indirect Labor

Mr. Grothe said he does not believe the greatest possibilities of elimination of waste lie in the direct-labor field but usually lie in indirect labor. His company takes great pains to have employes who can do two or more types of operation and finds this a great asset in any change of production schedule. It also reduces labor cost to the minimum and is an asset in working with small inventories, as the absence of a few operators does not materially affect the output.

For indirect labor, ratios of supervisors, truckers, sweepers and so on are set up in relation to production by careful analysis, with particular attention to fixed and semi-fixed factors and those that parallel production. It is believed that an incentive that is paid automatically must be present to secure better performance than the standard set.

Maintenance of an even flow of production by utilizing the storage capacity of the customer, especially in seasonable goods, is important.

To enable one to set up intelligent budgets it is essential, declared Mr. Grothe, to have complete records broken down into as much detail as possible, and these must be in the same form as the operating records, which allow for a continuous check-back of actual performance against anticipated performance. Checking of these records against the budgets or standards should be done daily, if possible.

Proper assignment of labor requires careful watching, he continued, and proper records enable the company to continuously select the employes who best perform the various operations.

Exact records are constantly kept of scrap and repairs and are sent to all department heads. They provide the basis for discussion at the foremen's weekly meetings and the semi-weekly meetings of the factory executives. The departments responsible for these losses are penalized; also, the pay for supervision is reduced if a proper amount of time for set-up is exceeded. The length of runs of various operations, which has a direct bearing on set-up, is studied to find the most economical point. In the case of very long runs, process inspection is made more often to guard against piling up parts that may become unusable and require additional operations later. Short runs and quick turnover avoid reoperations and scrap. Good general and intelligent individual lighting for specific purposes is essential to low-production cost.

A method believed to be unique in the speaker's institution is that the operators do not use a time-clock but the supervisors do. The theory is that mere presence of the operators does not give production but that supervision sets the example and secures production from the operators.

Most of the new employes are obtained through requests and recommendations of present employes, which has a wholesome effect on labor turnover. Apprenticeship training is maintained in the tool-room and the apprentices attend a technical high-school two half-days per week on the company's time and pay. There is also a foreman's and assistant foreman's training course, which includes trips through other plants.

Cooperation Reduces Inventory 60 Per Cent

Supplementing his prepared paper, Mr. Grothe remarked that through cooperation of all divisions of his company a combined inventory of $4,000,000 was reduced in 4 years to $1,500,000; adoption of nitro-cellulose finishing released a great deal of room in the finishing department for increased production; it is a good plan to have some one who is not an engineer go over the factory or department layout, as he often finds more direct ways of doing things; a 60-per cent reduction in scrap and reprocessing has been effected by better inspection; and it is unwise to start too many new plans at the same time, as it is better to have a few plans working well than a number that are not working at all.

In the discussion, H. P. Sailor, production manager of the Hupp Motor Car Corporation, remarked that few realize what over-inventory costs; a recent check-up at the Hupp plant showed that it was carrying 5000 batteries at a cost of $10 per 1000 per month although the battery maker would be willing to supply them in lots of 1000.

Willis Wissler, of Ohio State University, said that applied economics is now emerging from the classroom and being applied to business, and he enumerated some of the principles of economics as applied to the subject under discussion.

Planning has a direct bearing on inventory and manufacturing time, while the incentive plan helps to reduce production cost, said Howard A. Lincoln, of the Sullivan Machinery Co. The company with which he is connected rewards indirect labor by monthly division of a pool made up of savings in actual cost of production over the estimated cost.

In answer to a question, Mr. Grothe stated that the reasons more manufacturing companies do not own their own foundries are that there is a greater excess of capacity in the foundry business than in any other industry and that to operate a foundry economically often calls for more work than a company needs for itself. Similarly, his company saved money by leasing out its varnish and glue-making departments; a company should not spread out its efforts too thin. Other points he made were that it is advisable to have the heads of the sales department sit in on the planning of the production schedule, as this gives them some of the responsibility and an incentive to go out and sell the production, possibilities of reducing inventory in any item always exist if studied carefully and the cooperation of the suppliers is enlisted and consolidation of separate plants results in saving floor area and equipment and in more standardization of the product.

Time Waste Causes Greatest Loss

Recognition that there are control points in manufacturing expenditures is the first step toward locating causes of unnecessary expenditures, declared Wallace Clark, consulting management engineer, in the paper read by Mr. Donald. In the production of an assembled product the principal control-points are the assembly operations, whereas in manufacturing processes the operations that require most time, where most spoilage occurs, where cost of equipment is greatest, or the operation which sets the pace for the rest of the plant are the control points. Material wastes are less important than lost time, hence reduction of unnecessary expenditures consists principally in locating and eliminating waste of time of machines and workmen.

It is convenient to divide the search for lost time into investigation of (*a*) time when machines are not running and the reason they are idle and (*b*) when they are running, the reason that they do not produce at capacity. The simplest and most effective means of showing whether machines are running is by Gantt machine-record charts, which also show why they do not run and the cost of maintaining them in idleness. Groups of machines with greater or less capacity than groups performing preceding or succeeding operations are often discovered by tracing back the causes of machine idleness from control points. Idleness may be due to changes in product or difficulty in forecasting demand, and careful study results in adoption of a definite policy regarding disposal of equipment used for making products that have become obsolete. When machines are idle due to repairs, investigation usually leads to better inspection, lubrication, maintenance of tools, or to making repairs outside of regular working hours, according to Mr. Clark.

In the automotive industry interruptions in the supply of materials have been reduced to the minimum by good scheduling and by strict standardization of the products.

Lack of trained operators sometimes makes it impossible to run machines but in normal or subnormal conditions this does not cause much idleness, and when it does, it leads to improvement in the employment department, a higher wage scale or better working conditions.

Machine Idleness May Be Ruinous

Idleness of machines due to lack of work frequently amounts to 75 per cent of the total idleness, because American manufacturing plants in general are equipped to produce more than consumers can afford to buy. The determination of policy with regard to this cost of idleness is of paramount importance in many plants and sometimes makes or breaks the business, asserted the speaker. It is increasing in importance because productive capacity is growing faster than consumption, and under present competitive conditions it is impossible to include in prices more than a fraction of the cost of idleness of equipment unless the producer has at least some control over the market.

Wastes that occur when machines are running can be discovered by comparing the quantity of work done on each machine with a predetermined standard-output. If dependable standards have not been developed, a tentative standard based on a foreman's estimate of a fair day's-work for an average operator may be used. The quantity may be increased later.

When any new record of production is started, the workers have a tendency to lower the quality of the product. It is advisable, therefore, to fix a definite standard of quality and provide a force of inspectors to maintain it.

In investigating high production-costs at control points, a comparison of actual output with standards reveals many losses of time due to machines and tools that need repairs, or to materials received from previous operations in such condition that standard production on the key operation is impossible. In most cases, however, small production on machines that are running leads to consideration of the operator. The losses may not be his fault but they can be avoided only through him. Failure to meet a standard may be due to lack of training of the operator or to lack of the necessary skill. Only adequate training can correct this, or the operator, though well trained, may be too slow for the work and should be transferred to work for which he is better suited. Physical or mental conditions may, at times, result in decreased output by an operator. Inadequate lighting or ventilation, or fatiguing work, may cause the physical condition. Mental conditions resulting in subnormal production are due to a variety of causes.

Changes in Methods To Control Losses

In many cases as soon as the cause of losses is determined the necessary executive action is taken to stop them, but many losses are not easy to stop and it becomes necessary to install new and better methods of control. Machine idleness due to lack of material may require installation of a store-keeping method that will assure material on hand when needed and at the same time make possible a quick turnover of investment. The important features of such a system are the physical separation and marking of order points, keeping various lots of material separate while in stock, a storeroom conveniently laid out, and a well-trained personnel.

Machines idle waiting for following operations may lead to changes in equipment to provide better balance or to rearrangement of the layout of the plant. In case of difficulty with materials, it may be worthwhile to extend or reorganize the inspection department.

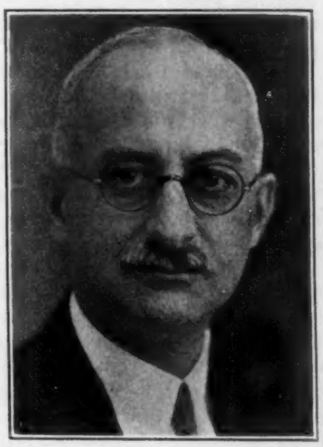
If machines are idle waiting for orders or materials that are in the plant, it sometimes is necessary to install a better method of planning and of getting the plans executed.

An executive wants to know how much the losses amount to in dollars and cents. This leads to installation of cost-keeping methods which separate costs of idleness from cost of work. When the causes of unnecessary expenditures have been located and the action for their control has been indicated, it remains for the executive to take that action and lead his organization toward the goal of low manufacturing-costs.

HAS ELIMINATED STOREROOMS

Closely Timed Purchasing Schedule Brings Materials Direct to Assembling Lines

How reduction and control of inventory have been effected by elimination of storerooms and a careful purchasing schedule was told at the afternoon session by Carl J. Sherer, treasurer of the Marmon Motor Car Co. Dispensing with storerooms necessitates very close timing of receipts of shipments of materials and reduces inventories of materials to a close approach to the zero point at which management in industry is aiming. The system has been in operation by the Marmon Company for the last 3 years, and discussion following delivery of the paper brought out the fact that the same system has been followed for 2 years at the Pontiac plant of the Oakland Motor Car Co., and is a sign of a new development.

Carl J. Sherer L. I. Shaw
ELIMINATING STOREROOMS AND RAW MATERIAL INSPECTION WERE THEIR TOPICS

Describing the system, Mr. Sherer said that no purchasing department alone can abolish storerooms; it must be aided by management control and requires thorough analytical study of all elements in the situation. A sales forecast is the first essential and one that cannot be overemphasized. This determines the materials that will have to be purchased and the finished articles that must be produced and sold. Fundamental requirements are definite production and purchasing schedules, study of the reliability of vendors and proper plant layout.

A 12-months' forecast gives a picture of anticipated production, but the actual schedule is based on 3-month periods, with 1-month releases of material orders. This schedule determines what materials must be purchased to maintain the smallest possible inventory consistent with uninterrupted production. The quantity requirement determination is based on careful analysis of the production schedule on each component part. The time element of different operations is important in this analysis, transit time of the vendors' shipping schedules must be studied and allowances of from 2 to 7 days must be made for variables. The purchasing schedule is shown in graphic form, as are also the quantities of materials received. Reliability of the suppliers is of primary importance, particularly in the case of special products that are not easily available from other sources. Receipts of materials are entered twice daily, and daily reports are made of the status of the following-up of shipping orders and of production of finished cars.

All storerooms are eliminated in the plant layout and receipts of materials are trucked directly from freight cars to the ends of sub-assembly lines in the plant.

Visible Inventory Means Instant Control

The small quantities of stock that are carried pile up at the ends of the sub-assembly feed lines. This visible inventory means instant control, but it also means that very close coordination and timing are required. Important advantages gained are that no storekeepers are employed, there is no trucking to and from stores, the rate of inventory turnover is high, and the inventory investment, taxes and insurance are low.

In the discussion Chapin Hoskins, of the A. W. Shaw Co., pointed out that the study of reliability of the supplier by going into his plant and keeping track of his production marks a new development of which four examples had come to his attention in the preceding 36 hr. He said industry has its financial credit system, and he inquired if this is not building up a new production credit system.

Replying to a question, Mr. Sherer said that one follow-up man and five clerks keep track of vendors' orders and shipments.

A. J. Brandt, vice-president in charge of operations of the Oakland Motor Car Co., said that this same system of eliminating storerooms has been followed for 2 years by their Pontiac plant and has resulted in an average turnover of materials 24 times a year, and the turnover rate has sometimes reached a maximum of 48 times.

There was much discussion of the effect of this policy upon the vendor and whether he follows the same plan with his suppliers or must himself carry surplus stock. Mr. Sherer explained that his company tries to deal fairly with the vendor by forecasting 1 year's requirements but making commitments for only 3 or 4 months and by having some contracts based on fluctuations of the price of material that goes into the vendor's product.

A representative of the foundry industry said that it stands to reason that no industry will continue to accept supplies and pile them up at a time of declining production, therefore the vendor also must use scientific control and find a way to meet releases calling for large increases or decreases. Another discusser pointed out that if there is to be a piling-up of materials it is better to pile up raw materials than fabricated products. E. G. Hickson, of the White Sewing Machine Co., said that if vendors will work out the Marmon and Oakland companies' scheme for themselves their problem will be simplified and the excess will accumulate in raw materials.

How Raw-Materials Inventory Is Controlled

A reservoir of materials is necessary somewhere along the line of manufacture from raw material to finished product to take care of the overflow in periods of decreasing production and to supply the deficiency in periods of increasing production, declared J. E. Padgett, of the Spicer Mfg. Corporation. A large inventory of finished and process stock means a much greater investment than a large inventory of raw materials. A transfer of inventory to the supplier of materials is satisfactory to him if the demands are steady or are known long enough in advance; otherwise no saving is made, because the service of the vendor in carrying material for the customer becomes part of his cost and this added burden must be reflected in his prices.

Raw-materials stores must be kept by the maker of a number of different products to (*a*) take care of sudden increases in demand for any or all products; (*b*) allow time for inspection and testing; (*c*) provide for continuation of production in case of rejection; (*d*) provide for shipping, receiving, and recording in economical quantities; and (*e*) carry production along until the supplier of the raw material is again making the particular size or kind of product required.

The object of control of raw-material stores, said Mr. Padgett, is to reduce carrying charges for inventory, eliminate the expense of obsolescence due to changes in the product, eliminate idle-time losses, and secure the lowest possible prices by cooperation with the vendor. Such control is not a matter of paper records, which are of minor importance; it is a vital matter of management policy, with coordination among all departments to make it function. Standardization and simplification of materials help to reduce inventories.

The first step in this control is to decide upon the kind of material wanted for a certain product, then detail specifications are drawn up and the prospective suppliers are investigated to make certain that they can and will supply the materials in the quantities and at the times wanted, and will cooperate to reduce future prices by development of less costly materials and in other ways.

Trial shipments are then received until the suppliers have become educated to the purchaser's requirements. This reduces rejections, scrap, trouble, and loss of time, and also greatly reduces inventory, because a large surplus is not needed for protection in case a shipment is unsatisfactory.

Speculation in materials must be eliminated if inventories are to be controlled, Mr. Padgett declared, as it has been discovered in most lines of business that obsolescence more than offsets the price differential and, as speculation usually occurs on a rising market, the excess on hand when the market falls must be depreciated. The organization as a whole must be trained to hold inventories to the minimum and secure the fastest turnover possible.

The succeeding step is the actual commitment for materials for manufacture and determination of the inventory to be carried. These are interlocked with the general production program, which, in the case of the company with which the speaker is connected, is based on a sales forecast that is issued once a month and shows actual and estimated sales conditions for the succeeding 3 months. This forecast goes to the control department, which also obtains information from the production manager and superintendents of the plant and prepares a manufacturing program for the coming month. Raw-material requirements are then estimated for this and the two following months and show the expected production of each type and size of product for the 3-months' period.

A material release is then issued just before the beginning of the month and may be above or below the sales forecast, due to a policy of flattening out the production curve by producing standard products in low-production periods and using this surplus in high-production periods. As all productive labor is paid on the group basis, this steady production is an asset in getting the best results from the groups. The material release also includes a definite program of control of inventory of raw, rough and finished materials.

Inventory Kept in Daily-Requirement Terms

About 18 months ago, said Mr. Padgett, the company changed the method of scheduling and of inventory control from a basis of actual unit figures to a basis of days representing average daily requirements of material items for a given production of finished units. The whole organization has now acquired the habit of talking and thinking of all

(*Continued on p.* 614)

STANDARDS COMMITTEE DIVISION REPORTS

The following Division Reports will be submitted to the Standards Committee for approval at the meeting this month

STANDARDS COMMITTEE MEETING MAY 25

To Be Held at French Lick during the Summer Meeting of the Society

In this issue of THE JOURNAL are printed reports that have been prepared for submission to the Standards Committee and the Society by five Divisions of the Standards Committee since the Annual Meeting of the Society last January. These include reports that have been submitted to the Society by Sectional Committees functioning under the procedure of the American Engineering Standards Committee, for which the Society is a sponsor. The Society's Standards Committee Regulations require that such reports be assigned to Divisions of the Standards Committee and that the same procedure be followed throughout as for reports originating in the Divisions. In some cases, these reports are submitted also for approval and adoption by the Society as part of the S.A.E. Standards as well as for American Standards under the procedure of the American Engineering Standards Committee.

All of the reports are submitted at this time for approval after having been thoroughly considered by their respective Divisions and as wide publicity as possible given them by publication in this or previous issues of THE JOURNAL. The reports as now presented are believed to be in acceptable form and any proposed changes should be only in the nature of important constructive ones and carefully considered. Under the Standards Committee procedure, these reports may be approved as presented, amended within limitations or referred back to their respective Divisions for sufficient reason. The action taken on them by the Standards Committee will be passed upon by the Council and the general business session of the Society, looking toward their approval for submission to letter ballot of the members of the Society as the final step in the procedure. The letter ballot will be counted 30 days following the Standards Committee Meeting and if affirmative, the reports will then be published in the S.A.E. HANDBOOK.

Rejection or major changes in any of the reports will require that they be sent back to their Divisions and that they cannot be passed upon before the Annual Meeting of the Society next January. In voting on the reports the Standards Committee Regulations require that only members of the Standards Committee do so.

ELECTRICAL EQUIPMENT DIVISION

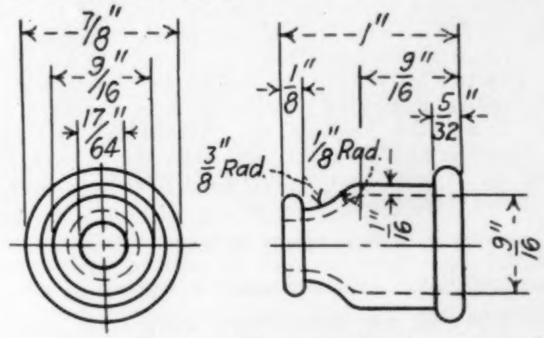
PERSONNEL

B. M. Leece, *Chairman*	Leece-Neville Co.
A. R. Lewellen, *Vice-Chairman*	Chevrolet Motor Co.
Azel Ames	Kerite Insulated Wire & Cable Co.
G. D. Becker	Underwriters Laboratories, Inc.
A. K. Brumbaugh	White Motor Co.
W. B. Churcher	Leece-Neville Co.
Bruce Ford	Electric Storage Battery Co.
W. S. Haggott	Packard Electric Co.
C. T. Klug	Willard Storage Battery Co.
T. L. Lee	North East Electric Co.
A. D. T. Libby	Representing Automotive Electric Association
D. M. Pierson	Dodge Bros.
F. H. Prescott	Delco-Remy Corporation
E. S. Preston	Chicago Electric Mfg. Co.
B. M. Smarr	General Motors Corporation
T. E. Wagar	Studebaker Corporation of America

7-MM. DISTRIBUTOR NIPPLE PROPOSED

Subdivision Favors Adoption of Only One Size as S.A.E. Recommended Practice

The Subdivision on Distributor Nipples has recommended to the Division the approval of specifications for the 7-mm. size as illustrated and recommends that no further consideration be given to the 9-mm. size owing to the exceedingly limited use of this size of nipple. Should increased usage warrant standardization of the 9-mm. size, this will again be taken into consideration.



PROPOSED DISTRIBUTOR NIPPLE

DISTRIBUTOR-ROTOR ELECTRODE

New Terms Proposed for Inclusion in Electrical Equipment Nomenclature

As a result of discussion had at the meeting of the Standards Committee in January, on the advisability of changing the Division's report from the term "load limit controller" to "load limiter," the report was referred back to the Division. Further consideration indicates the advisability of approving the report as originally submitted, it being considered that the term "load limit controller" is not too long, as was previously suggested. Therefore, the original report, reprinted below from the January Standards Committee Division Reports, is resubmitted for approval:

> The Society recently received an inquiry as to the proper name for that part of a timer-distributor rotor from which the high-tension spark jumps to the cap segments in the type of timer-distributor rotor that has a small electrode rather than a carbon brush. The term suggested for adoption was distributor-rotor-electrode and, as the members of the Division considered this as descriptive as any that could be used, the Division has recommended that it be added to the S.A.E. Nomenclature, immediately following the term Distributor-Rotor Brush on p. K7 of the S.A.E. HANDBOOK.
>
> The Subdivision on Ground-Return Wiring System has as a result of its work proposed that the term Load-Limit Controller be included in the S.A.E. Nomenclature to designate the protective element that is fre-

quently used in the generator circuit to prevent overload on a voltage-regulated shunt-wound generator. The Division also recommends that this term be inserted in the standard nomenclature, immediately following the term Current-Voltage Regulator on p. K9 of the S.A.E. HANDBOOK.

GROUND-RETURN WIRING SYSTEMS

Present Standard Cancelled and New Recommended Practice Proposed

The report on ground-return wiring systems, which was submitted by the Division to the Standards Committee in January and was referred back for further consideration as to the advisability of publishing this type of specification in the S.A.E. HANDBOOK as a standard, has been redrafted, taking into consideration the various controversial points brought out in the discussion at the Standards Committee Meeting.

The need for grounding the positive side of the battery in motorcoach and motor-truck wiring systems where a voltage-control system is used made it advisable that this point be covered in the specifications. However, in view of the fact that there is a great difference of opinion as to which terminal should be grounded in passenger-car systems and because practice in this regard is about equally divided, a positive ground is specified only for systems where voltage control is used. This will cover passenger-car systems, should voltage control be adopted for this type of vehicle in the future; and otherwise leave the choice of terminal to be grounded for decision by the individual designer.

The Division recommends that the present S.A.E. Recommended Practice on Wiring Color-Code be incorporated with the proposed recommended practice on ground-return wiring systems, under the heading of "Automobile Wiring" as S.A.E. Recommended Practice, and that the present S.A.E. Standard on Ground-Return Wiring Systems be cancelled. The proposed specifications follow:

AUTOMOBILE WIRING

(S.A.E. Recommended Practice)

The following recommendations have been adopted by the Society as guides for the designing and installing of electric wiring-systems in motor-vehicles in accordance with acceptable engineering practice. Economy, operating safety, efficiency and accessibility were the basis of the recommendations for wiring. To simplify the installing and connecting of the wiring in motor-vehicles and to afford a positive means for identifying the principal circuits in service or in replacing such wiring, the following recommended color-code, if not followed completely, should serve as the basis for the identification of wiring circuits wherever possible.

GROUND-RETURN WIRING SYSTEMS

Definitions.—The systems of installation commonly known as two-wire or single-wire, shall be termed respectively "insulated-return" and "ground-return" systems.

Installations in which the chassis frame is used as part of the return circuit shall be considered as ground-return systems.

Insulated Cable.—All insulated cable should conform to the S.A.E. Standard, and the S.A.E. recommended colors for wiring should be used as a means of identification. Terminals on other than starting-motor cables should be clamped to the insulation and soldered to the conductors. S.A.E. Standard terminals or lugs should be used on starting-motor cables. Conductor cross-sections should be not less than the equivalent of No. 16 B. & S. gage and the potential loss at normal load should not exceed 3 per cent.

Conduit.—Insulated cable should be protected by metal armor, or unpacked metallic or non-metallic covering except where otherwise protected or not in contact with metal surfaces. Metallic conduit should be provided with ferrules having rounded edges at open ends and where it enters junction-boxes. Metallic conduit covering insulated cable leading to a connector should be soldered inside of a sleeve member of the connector. Non-metallic covering should be provided with metal clamps at the entrance to junction-boxes or at connectors. Wires unprotected by conduit should be cleated at intervals not exceeding 28 in. Wires protected by conduit should be cleated at intervals of not more than 36 in. with metal clips secured by bolts or wood screws. Staples should not be used. No wire should be nearer to the exhaust-pipe than 2 in. The minimum clearance of 1 in. should be maintained between any running line of conduit or wires and the carbureter, gasoline pipe, gasoline tank, or any moving part. The edges of all holes in metal members through which cables not in conduit pass should be rolled or should be bushed with rubber bushings.

Grounding.—Wherever a conductor is connected to ground, it should be accessible for repair. Ground-return connections should be made to the chassis frame or to a substantial part which is firmly attached to the frame by properly prepared ends of the conductors. The positive side of the battery should be grounded when a voltage-control system is used. The surfaces on which the terminals make contact should be clean and free from oxide or paint and preferably tinned.

Battery Installation.—The storage-battery compartment, or metal parts near the storage-battery, should be painted with an acid-resisting paint and should have openings to provide ample battery ventilation and drainage. At the point where the live line passes through a metal compartment, the cable should be protected against grounding by an acid and waterproof insulated bushing. Where a battery and a gasoline tank are both placed under the driver's seat, they should be partitioned from each other and each compartment should be provided with an independent cover, ventilation and drainage.

Overload Protective Devices.—The current to all low-tension circuits, except starting-motor and ignition circuits, should pass through protective devices connected to the battery-feed side of switches. The circuits should be arranged so that the opening of a protective device will not extinguish all the lights. The inspection-lamp plug-socket should be connected to an unprotected live circuit. If a permanently connected inspection lamp or cord is installed, it should be protected independently of the lighting.

Protection Against Accidental Short-Circuits.—Connecting-posts on fuse and junction-blocks should be enclosed as a protection against accidental short-circuits.

WIRING COLOR-CODE

Passenger-Car Wiring for Use where Cable is Bought in Form of Harness

RED (UNPROTECTED WIRES)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Overload-Breaker or Fuse
All Other Unprotected Wires

RED WITH YELLOW TRACER

Low-Tension or Primary Ignition

RED WITH BLACK TRACER

Ammeter to Battery

YELLOW (PROTECTED WIRES)

Horn Feed
Signal-Lamp Switch Feed
Body-Lighting Switch Feed
Protective Devices to Lighting Switches
All Other Protected Wires

BROWN WITH BLACK TRACER

Lighting Switch to Junction Block (Parking Lamp)
All Ground Connections (except Battery Ground)

BLACK

Lighting Switch to Tail-Lamp

BLACK WITH RED TRACER

Bright Head-Lamps (or Upper Beam)

GREEN

Dim Head-Lamps (or Lower Beam)
Signal-Lamp (Switch to Lamp)

Passenger-Car Wiring for Use Where Cable Is Bought in Coils

RED (UNPROTECTED WIRES)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Battery
Ammeter to Protective Devices
Low-Tension or Primary Ignition
All Other Unprotected Wires

YELLOW (PROTECTED LIVE WIRES)

Horn Feed
Signal-Lamp Switch Feed
Body-Lighting Switch Feed
Protective Devices to Lighting Switches
All Other Protected Live Wires

Motorcoach and Motor-Truck Wiring for Use where Cable Is Bought in Coils

RED (UNPROTECTED WIRES)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Battery
Ammeter to Overload-Breaker or Fuse
Low-Tension or Primary Ignition
All Other Unprotected Wires

YELLOW (PROTECTED WIRES)

Horn Feed
Signal-Lamp Switch Feed
Body-Lighting Switch Feed
Protective Devices to Lighting Switches
All Other Protected Wires

BROWN WITH BLACK TRACER

Generator to Cut-Out or Regulator to Ground
All Ground Connections (except Battery Ground)

BLACK

Bright Head-Lamps (or Upper Beam)
Body-Lamp Feed (Switch to Lamp)

BLACK WITH RED TRACER

Dim Head-Lamps (or Lower Beam)
Tail-Lamp

GREEN

Signal-Lamp (Switch to Lamp)
Signal-Lamp (To Indicator or Pilot)

PASSENGER-CAR BODY-LIGHTING SWITCHES

Division Approves Proposed Specifications for Mounting-Hole Dimensions

Because of the slight variations existing in mounting-screw hole spacing it was considered advisable to undertake standardization of the mounting-hole dimensions of body-lighting switches. A subdivision, on which were representatives of the principal switch manufacturers, submitted a report recommending mounting dimensions for the three sizes of switch which cover the requirements of passenger-car manufacturers. It is not considered feasible at this time to undertake the standardization of motorcoach-switch mountings owing to the fact that a great variation in body design requires special switches in the majority of cases. The report, which follows, covers body-hole dimensions and screw-hole spacing and is submitted for approval as an S.A.E. Recommended Practice:

PASSENGER-CAR BODY-LIGHTING SWITCHES

MOUNTING-HOLE DIMENSIONS

Barrel Type

Hole Diameter, In.	Screw-Hole Spacing Center-to-Center, In.	Hole Depth, In.
7/8	1-3/16	1-1/8
7/8	1-13/16	1-1/8

Rectangular Type

Hole Dimensions, In.	Screw-Hole Spacing Center-to-Center, In.	Hole Depth, In.
1½ x ⅝	2⅛	1¼

INSTRUMENT MOUNTINGS AND CONNECTIONS

Further Revisions of and Additions to Present Instrument-Mounting Specifications

Owing to the fact that the present specifications for instrument mountings do not permit the mounting of electrical instruments made of heavy-gage material, which increases the outside diameter of the body, it was considered advisable by the Subdivision on Instrument Mountings to recommend a revision of the present mounting specifications to permit the use of this type of instrument. The mounting-hole dimensions have, therefore, been revised to indicate dimensions which will permit the use of either the 2.000 or the 2.027-in. instrument. It is also recommended that the present specifications be supplemented by a table covering binding-post sizes for instruments of 0-30 amp. capacity and 30-50 amp. capacity.

The specification covering ammeter polarity, giving uniform reading "charge to right of zero" and "discharge to left of zero," was also recommended by the Subdivision, but this part of the report was not approved and has been tabled for future consideration by the Division.

The proposed specifications are as follows:

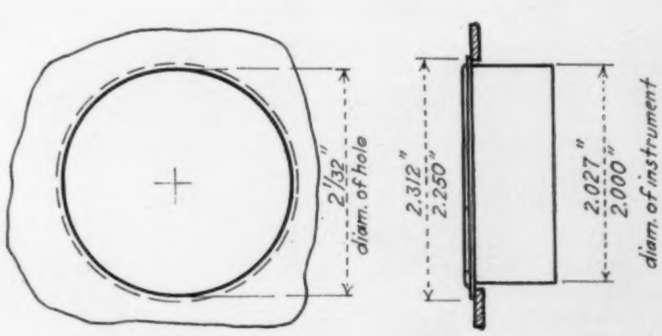
INSTRUMENTS AND GAGES

These specifications are intended to cover mounting dimensions and connections for electrical instruments and oil-pressure, air-pressure, gasoline-capacity and thermal-indicator gages.

INSTRUMENT MOUNTINGS

CLAMP-TYPE

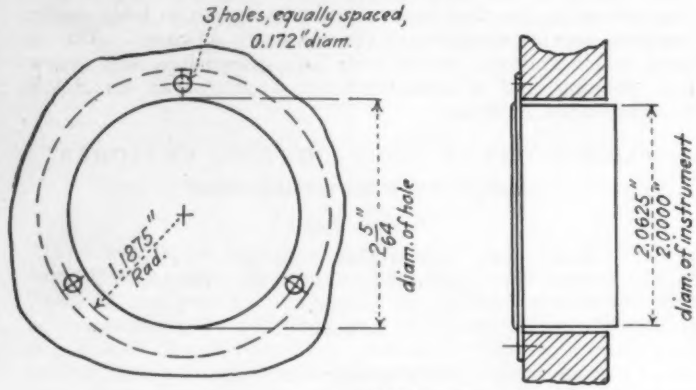
(S.A.E. Standard)



	Minimum	Maximum
Diameter of Instrument or Gage, in.	2.000	2.027
Diameter of Hole, in.	2.030	2.040
Diameter of Flange, in.	2.250	2.312

FLANGED SCREW TYPE

(*S.A.E. Standard*)



	Minimum	Maximum
Diameter of Instrument or Gage, in.	2.000	2.0625
Diameter of Hole, in.	2 5/64	2 5/64
Diameter of Screw Hole Circle, in.	2 3/16	2 3/16

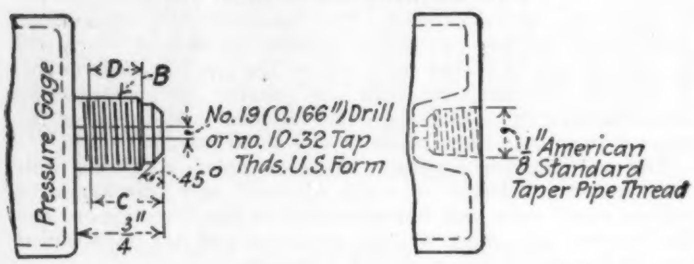
ELECTRICAL-INSTRUMENT BINDING-POSTS

(*S.A E. Recommended Practice*)

Capacity, Amp.	Binding-Post Size and Thread Pitch
0-30	10-32
30-50	12-32

PRESSURE-GAGE CONNECTIONS

(*S.A E. Recommended Practice*)



Tubing Diameter	(*B*) NF—2	(*C*) Minimum	(*D*) Minimum Usable Thread
1/4	7/16—20	1/2	11/32
5/16	1/2—20	9/16	3/8
3/8	5/8—18	5/8	13/32

The type of connection shown at the right is intended for pressure-gages where the type of construction shown at the left is not applicable.

DOME-LIGHT LAMP-SOCKET SPECIFICATION

Double-Contact Base for Motorcoach Body-Lights Recommended by Subdivision

The Division recommends approval of the Subdivision's report on dome-light lamp-sockets as an S.A.E. Recommended Practice as follows:

All motorcoach body-lights of 6 cp, or over shall be of the double-contact type.

IRON AND STEEL DIVISION

PERSONNEL

J. M. Watson, *Chairman*	Hupp Motor Car Corporation
J. H. Nelson, *Vice-Chairman*	Wyman-Gordon Co.
J. R. Adams	Midvale Co.
R. J. Allen	Rolls-Royce of America
A. L. Boegehold	General Motors Corporation Research Laboratories
Henry Chandler	Vanadium Corporation of America
J. D. Cutter	Fafnir Bearing Co.
A. H. d'Arcambal	Pratt & Whitney Co.
B. H. DeLong	Carpenter Steel Co.
F. P. Gilligan	Henry Souther Engineering Corporation
H. W. Graham	Jones & Laughlin Steel Corporation
Walter G. Hildorf	Reo Motor Car Co.
E. J. Janitzky	Illinois Steel Co.
J. A. Mathews	Crucible Steel Co. of America
W. C. Peterson	Donner Steel Co.
E. A. Portz	Central Alloy Steel Corporation
S. P. Rockwell	Stanley P. Rockwell
R. B. Schenck	Buick Motor Co.
W. R. Shimer	Bethlehem Steel Co.
H. P. Tiemann	Carnegie Steel Co.
E. W. Upham	Chrysler Corporation
T. H. Wickenden	International Nickel Co.

HEAT-TREATMENT DEFINITIONS

Report of Joint Committee Approved for Publication as General Information

A joint committee, composed of representatives of the Society of Automotive Engineers, the American Society for Testing Materials and the American Society for Steel Treating and organized to formulate definitions of terms relating to heat-treatment operations, recently completed its report which, as a matter of procedure, was presented to the Iron and Steel Division for approval. The report was approved by the Division by a two-thirds vote.

It was also considered advisable that the definitions be published in the S.A.E. HANDBOOK, in Section IX, of the Iron and Steel Specifications, as General Information. Therefore, the Division further recommends that the following specifications be adopted by the Society as General Information.

During recent years certain confusion has arisen in regard to the meaning of commonly used heat-treating terms. For instance, in one locality or trade, any operation of heating and cooling resulting in a softening of the material is being called annealing, whereas in other places to "anneal" means not primarily "to soften" but to heat to above the critical temperature and cool very slowly. Similar confusion as to meaning and application exists in regard to other terms and as a result "annealing," "tempering," "normalizing," and the like are being used by different people to mean widely different things.

In any attempt to define accurately the terms commonly used in connection with heat-treatment, the first question to decide and the most important one is: do the terms relate to the heat-treatment operation itself or to the results obtained by the treatment? In other words, is the term indicative of the structure or the condition obtained or of the operation performed?

After careful consideration, it appears most logical and most in keeping with present day usage to have the terms so defined that they shall mean definite operations and shall not be considered as referring to the resultant structures or general conditions.

By "critical temperature range," as used in the Definitions, is meant that temperature range illustrated by the diagram reproduced at the left of Fig. 1, which is taken from Howe.

Heat-Treatment.—An operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state.

Note.—This is for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

Quenching.—Immersing to cool.

Note.—Immersions may be in liquids, gases or solids.

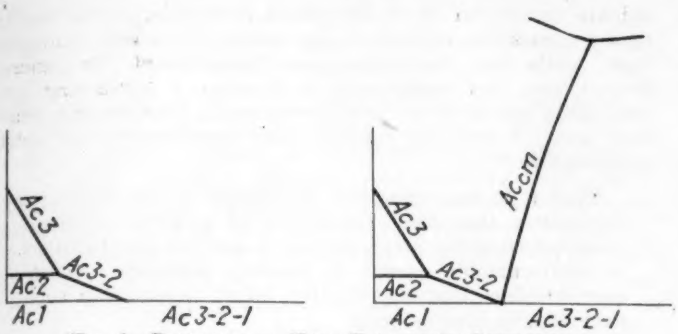


FIG. 1—DIAGRAM FOR HEAT-TREATMENT DEFINITIONS

Hardening.—Heating and quenching certain iron base alloys from a temperature either within or above the critical temperature range.

Annealing.—Annealing is a reheating and cooling operation of a material in the solid state.

Note a.—Annealing usually implies a relatively slow cooling.

Note b.—Annealing is a comprehensive term. The purpose of such a heat treatment may be:

(1) To remove stresses
(2) To induce softness
(3) To alter ductility, toughness, electrical, magnetic or other physical properties
(4) To refine the crystalline structure

In annealing, the temperature of the operation and the rate of cooling depend upon the material being heat treated and the purpose of the treatment.

Specific heat treatments coming under the comprehensive term "annealing" are:

Normalizing.—Heating iron base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

Note.—In the case of hypereutectoid steel, it is often desirable to heat above the Ac_{cm} line, as shown in the diagram at the right of Fig. 1.

Spheroidizing.—Prolonged heating of iron base alloys at a temperature in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.

Note a.—In the case of small objects of high carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.

Note b.—The object of this heat treatment is to produce a globular condition of the carbide.

Tempering (also termed *Drawing*).—Reheating, after hardening to some temperature below the critical temperature range followed by any rate of cooling.

Note a.—Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.

Note b.—Tempering meaning the operation of hardening followed by reheating is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

Malleablizing.—Malleablizing is a type of annealing operation with slow cooling whereby combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.

Note.—Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

Graphitizing.—Graphitizing is a type of annealing of cast iron whereby some or all of the combined carbon is transformed to free or uncombined **carbon.**

Carburizing (Cementation).—Adding carbon to iron base alloys by heating the metal below its melting-point in contact with carbonaceous material.

Note.—The term "carbonizing" used in this sense is undesirable and its use should be discouraged.

Case-Hardening.—Carburizing and subsequently hardening by suitable heat-treatment, all or part of the surface portions of a piece of iron base alloy.

Case.—That portion of a carburized iron base alloy article in which the carbon content has been substantially increased.

Core.—That portion of a carburized iron base alloy article in which the carbon content has not been substantially increased.

Cyaniding.—Surface hardening of an iron base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

S.A.E. STEEL 4615 SPECIFICATION REVISED

Carburizing Temperature Range and Manganese and Nickel Percentages Changed

Reconsideration of heat-treatments for S.A.E. Steel 4615 recommended by the Iron and Steel Division and approved at the Standards Committee meeting in January, as a result of criticism of the specified carburizing temperature as too low, has indicated the desirability of changing this temperature range in Heat-Treatment 4615-IV, and Heat Treatment 4615-V, as given on page D65b of the March, 1927, issue of the S.A.E. HANDBOOK.

The Division recommends that a change be made in Item 1 under each of these heat-treatments from "(1) Carburize at 1600 to 1650 deg. fahr." to "(1) Carburize at 1625 to 1675 deg. fahr."

In order that the manganese range of S.A.E. Steel 4615 may be in conformity with the standard range for carburizing steels, it is recommended that the manganese range of S.A.E. Steel 4615 be changed from 0.30–0.50 to 0.30–0.60 per cent.

Discussion was had of a suggestion that the Society adopt specifications for a molybdenum steel with a higher nickel-range than is included in the present specifications. It appeared to be advisable to change the nickel range of S.A.E. Steel 4615 rather than add a new specification for a steel whose composition would so nearly parallel 4615 steel. Therefore, the Division recommends that the nickel range of S.A.E. Steel No. 4615 be changed from 1.25–1.75 to 1.50–2.00 per cent.

CANCELLATION OF S.A.E. STEEL 1046

Lack of Use in Automotive Industry Basis for Recommending Elimination

In view of the fact that S.A.E. Steel 1046, which was originally included in the S.A.E. Steel Specifications at the request of the American Gear Manufacturers Association and which is not generally used in the automotive industry, and, because it is not the policy of the Society to include in its Steel Specifications steels peculiar to an industry other than the automotive field, the Iron and Steel Division recommends that S.A.E. Steel 1046 be eliminated from the S.A.E. Steel Specifications.

UNIVERSAL NUMBERING OF STEELS

Sectional Committee Recommends Discontinuing Project as Not Being Feasible

In June, 1922, at a meeting in the City of Washington of the Committee advisory to the Bureau of Ferrous Metals of the Department of Commerce, the subject of a universal or common system of numbering steels was discussed with the result that a sharp difference of opinion as to the advisability of undertaking the project was found, some of those present indicating their belief that the subject should

be considered, while others felt that it would be practically impossible to classify the engineering steels in general. No definite action was taken by the meeting but the American Engineering Standards Committee was advised regarding it. At the meeting of the Main Committee of the American Engineering Standards Committee on June 15, 1922, a general conference under the auspices of the American Engineering Standards Committee was authorized and invitations issued to a number of national organizations, Government Departments and individual companies. As the result of the conference that was held at the City of Washington in December, 1922, the American Engineering Standards Committee invited the American Society for Testing Materials and this Society to accept joint sponsorship of a Sectional Committee for the development of a numbering system for forging, casting and structural steels, including plates, but not including tool-steels, the numbering system to be based on definite specifications.

The American Society for Testing Materials and this Society accepted sponsorship for the project and organized the Sectional Committee, the members of which represented most of the national organizations likely to be interested in the problem. The first meeting of the Committee was held at the City of Washington in May, 1924, at which it developed from evidence before the Committee that no well-defined demand was apparent for the preparation of a universal steel-numbering code, and it was therefore decided that, to clarify the situation, the Committee should hold a meeting to which material engineers representing users of steels would be invited to discuss the subject and present their suggestions, particularly if they were in favor of such a code. The second meeting of the Committee was held at New York City in February, 1925. At this it was the sense of those present that, while there was interest of a general nature in the project, there was still no evidence of sufficient demand for such a system of numbering. A general study of the project and of several examples of systems in use that varied among themselves, such as those of the War and the Navy Departments, large industrial organizations and national engineering societies which were mostly combinations of letters, numbers and code symbols used to designate various steels, resulted in the conclusion that such systems are adequate in their own fields and do not lead to conflict or confusion. This study also emphasized the fact that any numbering-system is merely a convenient method of designation and is useful only insofar as each number is the symbol of a definite specification. To be accurate and comprehensive, such a system cannot escape being cumbersome, as it must be capable of covering the necessary chemical composition, physical properties and, on occasion, other detail data.

After considering the possibility of devising a numbering system that would not conflict seriously with those established in practice, and the difficulties in preparing such a system in view of the lack of general interest or demand for it, the Committee felt that it faced a serious question in deciding whether such a system of numbering would be of sufficient practical advantage to justify the amount of work necessary to formulate one. Accordingly, it was decided to send a questionnaire to the members of the Committee and to a number of large users of steels not represented on the Committee, asking whether (*a*) there is a well-defined need in their organizations for such a universal numbering system for steels based on definite specifications and (*b*) they would designate an individual in their organizations to work on this problem and attend Committee meetings. The replies that were received were as follows:

Question	(*a*) Yes	(*a*) No	(*b*) Yes	(*b*) No
Committee	3	15	12	6
Others	2	2	2	2
Total	5	17	14	8

At the third meeting of the Committee, held in Philadelphia on March 16 of this year, discussion of the replies to the questionnaire and of the subject in general indicated that, while the Committee had investigated the general project and had endeavored to develop a numbering system, there appeared to be no prospect of developing a practical one. Finally on motion, duly seconded, it was voted unanimously:

> That it is the consensus of opinion of the Sectional Committee that the preparation of a universal numbering-system for steels based on definite specifications is impracticable except by merely indexing existing specifications, and that further effort to establish such a system is inexpedient;
>
> That the Secretary of the Sectional Committee be instructed to prepare a brief covering the activities of the Sectional Committee which have led to this conclusion, and that such brief and this resolution be submitted to all the members of the Sectional Committee for their written approval and that on receipt of replies the matter be referred to the sponsor bodies for appropriate action.

At the time of printing this report in THE JOURNAL the written ballot of the Sectional Committee was not completed, but to make it possible to report this project and the action taken by the Sectional Committee to the Standards Committee and to the Society as one of the sponsors, the Iron and Steel Division has been asked to give it special consideration and to submit its recommendation to the Standards Committee at its meeting on May 25 at French Lick Springs, Ind. The personnel of the Sectional Committee is as follows:

F. P. Gilligan, *Chairman*	Society of Automotive Engineers
L. H. Fry, *Secretary*	American Society for Testing Materials
A. H. Beyer	American Society of Mechanical Engineers
R. L. Burke	American Marine Standards Committee
Perry R. Cassidy	American Boiler Manufacturers' Association
C. N. Dawe	Society of Automotive Engineers
W. R. Edwards	American Railway Association
Henry Gulick	American Electric Railway Association
E. F. Kenney	Association of American Steel Manufacturers
T. D. Lynch	American Society for Testing Materials
J. E. McCauley	Steel Founders Society of America
H. H. Morgan	American Society for Testing Materials
H. T. Morris	American Society for Steel Treating
J. G. Morrow	Canadian Engineering Standards Committee
G. L. Norris	Society of Automotive Engineers
F. W. Olcott	Federal Specifications Board
E. E. Thum	Representing general interests
H. P. Tiemann	Association of American Steel Manufacturers
C. A. Walker	Federal Specifications
F. W. Willard	Bell Telephone System

CHANGE IN MANGANESE LIMITS

Proposed Revision of Specifications for S.A.E. Steels 3415, 3435 and 3450

Acting on a suggestion that the manganese range of S.A.E. Steels 3415, 3435 and 3450 be brought into line with the manganese range of the 3200 and 3300 series steels, the Iron and Steel Division recommends that the manganese range for each of these three steels be changed from 0.45-0.75 to 0.30-0.60 per cent.

SPECIFICATION FOR S.A.E. STEEL 2512

Change to Permit a 0.50-Per Cent Variation in Nickel-Content Limits Recommended

The specifications of S.A.E. Steel 2512 at present indicate a nickel content that permits 0.75 per cent variation. It is the consensus of opinion of the Division that the nickel-content limits should be changed to be consistent with steels of the 2300 series, whose nickel range permits a 0.50-per cent variation. The Iron and Steel Division recommends that the nickel range of S.A.E. Steel 2512 be changed from 4.50–5.25 to 4.75–5.25 per cent.

PARTS AND FITTINGS DIVISION

Personnel

H. S. Jandus, *Chairman*	C. G. Spring & Bumper Co.
A. Boor, *Vice-Chairman*	Willys-Overland Co.
Joseph Berge	Joseph Berge Co.
A. K. Brumbaugh	White Motor Co.
R. V. Hutchinson	Olds Motor Works
W. C. Keys	U. S. Rubber Co.
G. L. McCain	Dodge Bros., Inc.
Ivan Ornberg	Hupp Motor Car Corporation
W. J. Outcalt	General Motors Corporation
C. W. Spicer	Spicer Mfg. Corporation
F. C. Stanley	Raybestos Co.
F. G. Whittington	Stewart-Warner Speedometer Corporation
H. T. Woolson	Chrysler Corporation

OILLESS BUSHINGS SPECIFICATIONS

Cancellation Recommended as Sizes Shown in S.A.E. Handbook Are Not Representative

At the Parts and Fittings Division meeting on March 31 the matter of revising the present S.A.E. Specifications for Oilless Bushings was discussed with Robert Thuner, of the O. & S. Bearing Co., who was present at the invitation of the Division. The Division was informed by Mr. Thuner that, because of the great variation in the design of brake cross-rods and other similar parts on which oilless bushings are used, it is in his opinion impracticable to reduce to practice any dimensional standardization of the bushings before the parts involved shall have been standardized.

With reference to the present S.A.E. Specification, which was formulated several years ago, it was found that the sizes shown in the S.A.E. HANDBOOK are not representative of oilless bushings used in the industry. Therefore, the Division recommends that the present S.A.E. Recommended Practice for Oilless Bushings be cancelled.

PROPOSED REVISION OF BUMPER STANDARDS

New Height and Over-All Length Specifications Recommended for Adoption

Owing to the fact that the present passenger-car is considerably lower than previous models, a revision of the present S.A.E. Standard on Bumper Heights is necessary. An attempt has been made in making this revision to meet the requirements of passenger-car designers from the viewpoint of appearances and also to provide that bumpers mounted according to the old standard and to the revised standard shall meet satisfactorily to afford the necessary protection. After a survey of the present practice of the leading passenger-car builders, a subdivision on Passenger-Car Bumpers presented the revision given below to the Parts and Fittings Division at its meeting on April 21. The Subdivision also considered recommending a revision of present mounting-hole dimensions, as well as new specifications for integral spring-horn type of mounting, but in view of a possible unfavorable patent situation existing on the latter type of mounting, it was decided to confine action at this time to a revision of the present height and length specifications.

The Division recommends the following revision of the present S.A.E. Standard on Bumper Heights and Lengths:

> Protective bumpers for passenger-cars, small motorcoaches and light delivery-trucks shall conform to the following dimensions:
>
> > The horizontal center-line of bumper face exclusive of fittings shall be 18 in., plus or minus ⅜ in. per in. of effective face, above the ground for front bumpers, and 19 in., plus or minus ⅜ in. per in. effective face, above the ground for rear bumpers or fender-guards.
> >
> > The minimum over-all length of front bumpers shall be 60 in. on passenger-cars having the standard 56-in. tread.
> >
> > The minimum dimension measured between the extreme ends of rear bumpers, or fender guards, shall be 60 in. on passenger-cars having the standard 56-in. tread.
> >
> > The minimum vertical-depth of bars for single-bar-type front and rear bumpers shall be 2 in.
> >
> > The bumper height shall be measured with the car supplied with the normal amount of water, oil and gasoline, but without passengers or other load.
> >
> > The vertical spread of contact face shall be the distance between the upper and lower edges of the outer bumper-elements, exclusive of any additional projecting parts.

FLEXIBLE-DISC TOLERANCES REVISED

New Limits for Parallelism of Faces and Thickness Recommended by Subdivision

After further consideration of the results of the survey of flexible-disc manufacturers and users with reference to suitable tolerances for thickness and parallelism of faces, a Subdivision presented a report which was approved at a meeting of the Parts and Fittings Division in Detroit on April 21. This is a revision of the present S.A.E. Recommended Practice, given on Page E11 of the March, 1927, issue of the S.A.E. HANDBOOK.

The report recommends that the thickness tolerances be changed from plus 0.020, minus 0.010, to plus or minus 0.020, and that a specification be added to the effect that the thickness of any one disc shall not vary by more than 0.010 in.

NOMENCLATURE OF SMALL RIVETS

Parts and Fittings Division Balloting on Proposed Change in Status of This Subject

At the January Meeting of the Society the report on Small Rivets that had been issued by a Subcommittee of the Sectional Committee on Bolt, Nut and Rivet Proportions was approved for adoption as Tentative American Standard. In the course of preparations for publishing the report, the proposal was made by a member of the Subcommittee of the Sectional Committee to change the status of the report from Tentative American Standard to American Standard and to change the name of Truss-Head Rivets to Truss-Head or Wagon-Box Head Rivets. This type of rivet was given in table No. 5 of the Sectional Committee's report that was printed on p. 21 of the January issue of THE JOURNAL.

At the time of preparing this issue of THE JOURNAL the majority of the members of the Subcommittee had indicated their approval of the proposed changes and a letter-ballot of the Sectional Committee was in progress. A simultaneous letter-ballot of the members of the Parts and Fittings Division of the Standards Committee was also being taken, with the proviso that their vote is dependent upon the proposed changes being approved by the Sectional Committee. If the required ballots shall have been taken on the report by then, it will be submitted to the Standards Committee Meeting at French Lick Springs, Ind., on May 25, for approval by the Society as a sponsor for the Sectional Committee. Otherwise the report will not be so presented.

SPLIT AND TUBULAR RIVETS

Proposed Dimensional Specification for Approval as S.A.E. Recommended Practice

The Subdivision on Rivets, at a meeting of the Parts and Fittings Division on March 31, presented a report embodying a suggested S.A.E. Recommended Practice for Split and Tubular Rivets. Two manufacturers furnishing the bulk of these types of rivet to the automotive industry were represented on the Subdivision which succeeded in eliminating from the recommendations a large number of rivets which differ only by slight variation in head size.

The Parts and Fittings Division approved the report and recommends that the dimensional standards for split and tubular rivets shown in the accompanying drawings and tables be approved as S.A.E. Recommended Practice:

TUBULAR RIVETS

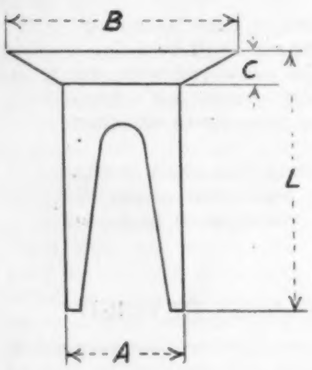
Cupped Countersunk Head

Body Diameter, In.[3] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Over-All Length, In.[4] (*L*)
9/64	5/16	1/8	9/32–3/4
3/16	3/8	1/8	9/32–3/4

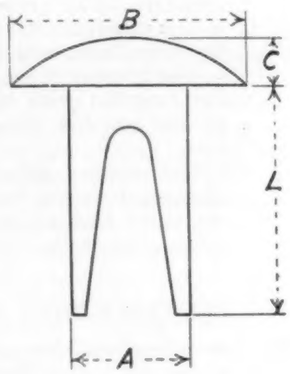
Flat Countersunk Head

Body Diameter, In.[3] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Over-All Length, In.[4] (*L*)
1/8	1/4	1/32	1/8 –1/2
9/64	5/16	3/64	1/4–5/8
3/16	23/64	3/64	1/4–3/4

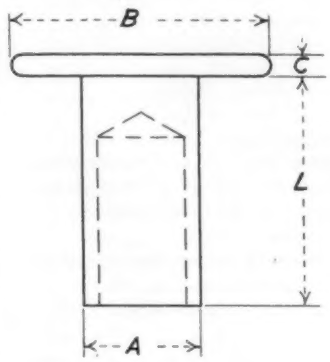
[3] Body diameter tolerance +0.005—0.000 in.
[4] Length tolerance ±0.005 in. Lengths increase in 1/32-in. steps.



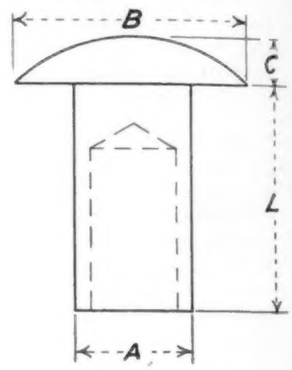
Flat Countersunk Head



Oval Head



Flat Head



Oval Head

SPLIT RIVETS

Flat Countersunk Head

Nominal Body Diameter, In.[1] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Over-All Length, In.[4] (*L*)
1/8	7/32	3/64	3/16–1/2
9/64	5/16	3/64	1/4 –3/4
9/64	3/8	3/64	1/4 –3/4
3/16	7/16	3/64	5/16–3/4

Oval Head

Nominal Body Diameter, In.[1] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Length under the Head, In.[2] (*L*)
3/32	9/64	1/32	3/16–1/2
1/8	7/32	1/32	3/16–3/4
9/64	5/16	3/64	3/16–3/4
3/16	11/32	3/64	1/4 –3/4

[1] Body diameter tolerance +0.007—0.000 in.
[2] Length tolerance ±1/64 in. Lengths increase in 1/16-in. steps.

TUBULAR RIVETS

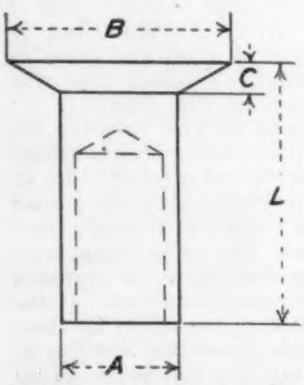
Flat Head

Body Diameter, In.[5] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Length under the Head, In.[6] (*L*)
1/8	1/4	1/32	3/32–3/8
9/64	21/64	1/32	3/16–5/8
3/16	7/16	3/64	1/4 –5/8

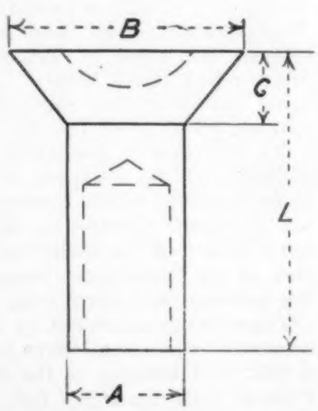
Oval Head

Body Diameter, In.[5] (*A*)	Head Diameter, In. (*B*)	Head Thickness, In. (*C*)	Length under the Head, In.[6] (*L*)
1/8	7/32	1/32	3/32–5/8
9/64	5/16	3/64	3/16–5/8
3/16	23/64	5/64	3/16–3/4

[5] Body diameter tolerance +0.005—0.000 in.
[6] Length tolerance ±0.005 in. Lengths increase by 1/32-in. steps.



Flat Countersunk Head

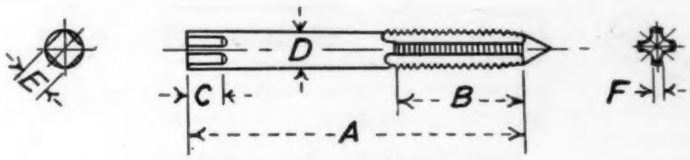


Cupped Countersunk Head

PRODUCTION DIVISION REPORT

PERSONNEL

E. N. Sawyer, *Chairman*	Cleveland Tractor Co.
L. F. Maurer, *Vice-Chairman*	Studebaker Corporation of America
G. E. Bechtel	White Motor Co.
Eugene Bouton	Chandler - Cleveland Motors Corporation
W. G. Careins	Nash Motors Co.
A. R. Fors	Continental Motors Corporation
A. H. Frauenthal	Studebaker Corporation of America
H. P. Harrison	H. H. Franklin Mfg. Co.
O. C. Kavle	Manufacturers' Consulting Engineers
R. R. Keith	International Harvester Co.
F. E. A. Klein	Pierce-Arrow Motor Car Co.
A. F. Misch	Peerless Motor Car Corporation



MACHINE SCREW TAPS—CUT AND GROUND THREADS

Size	Pitch-Diameter				Major Diameter					General Dimensions					
	Basic	Minimum	Maximum Cut Thread	Maximum Ground Thread	Basic	Cut Thread Minimum	Cut Thread Maximum	Ground Thread Mini mum	Ground Thread Maximum	Over-All Length, *A*	Thread Length, *B*	Square Length, *C*	Shank Diameter, *D*	Square Size, *E*	Land Width, *F*
0-80	0.0519	0.0524	0.0534	......	0.0600	0.0610	0.0625	......	......	1 5/8	5/16	3/16	0.1410	0.1100	.....
1-64	0.0629	0.0634	0.0644	......	0.0730	0.0740	0.0755	......	......	1 11/16	3/8	3/16	0.1410	0.1100	......
1-72	0.0640	0.0645	0.0655	......	0.0730	0.0740	0.0755	......	......	1 11/16	3/8	3/16	0.1410	0.1100	......
2-56	0.0744	0.0749	0.0759	......	0.0860	0.0875	0.0890	......	......	1 3/4	7/16	3/16	0.1410	0.1100	......
2-64	0.0759	0.0764	0.0774	......	0.0860	0.0875	0.0890	......	......	1 3/4	7/16	3/16	0.1410	0.1100	......
3-48	0.0855	0.0860	0.0870	......	0.0990	0.1005	0.1020	......	......	1 13/16	1/2	3/16	0.1410	0.1100	......
3-56	0.0874	0.0879	0.0889	......	0.0990	0.1005	0.1020	......	......	1 13/16	1/2	3/16	0.1410	0.1100	......
4-40	0.0958	0.0963	0.0978	......	0.1120	0.1135	0.1155	......	......	1 7/8	9/16	3/16	0.1410	0.1100	......
4-48	0.0985	0.0990	0.1005	......	0.1120	0.1135	0.1155	......	......	1 7/8	9/16	3/16	0.1410	0.1100	......
5-40	0.1088	0.1093	0.1108	......	0.1250	0.1265	0.1285	......	......	1 15/16	5/8	3/16	0.1410	0.1100	......
5-44	0.1102	0.1107	0.1122	......	0.1250	0.1265	0.1285	......	......	1 15/16	5/8	3/16	0.1410	0.1100	......
6-32	0.1177	0.1182	0.1197	0.1187	0.1380	0.1395	0.1415	0.1395	0.1410	2	11/16	3/16	0.1410	0.1100	......
6-40	0.1218	0.1223	0.1238	......	0.1380	0.1395	0.1415	......	......	2	11/16	3/16	0.1410	0.1100	......
8-32	0.1437	0.1442	0.1457	0.1447	0.1640	0.1660	0.1680	0.1655	0.1670	2 1/8	3/4	1/4	0.1680	0.1310	0.0420
8-36	0.1460	0.1465	0.1480	......	0.1640	0.1660	0.1680	......	......	2 1/8	3/4	1/4	0.1680	0.1310	0.0420
10-24	0.1629	0.1634	0.1649	0.1639	0.1900	0.1925	0.1945	0.1925	0.1940	2 3/8	7/8	1/4	0.1940	0.1520	0.0500
10-32	0.1697	0.1702	0.1717	0.1707	0.1900	0.1925	0.1945	0.1915	0.1930	2 3/8	7/8	1/4	0.1940	0.1520	0.0500
12-24	0.1889	0.1894	0.1909	0.1899	0.2160	0.2185	0.2205	0.2185	0.2200	2 3/8	15/16	9/32	0.2200	0.1650	0.0560
12-28	0.1928	0.1933	0.1948	0.1938	0.2160	0.2185	0.2205	0.2180	0.2195	2 3/8	15/16	9/32	0.2200	0.1650	0.0560

GENERAL SPECIFICATIONS

PITCH-DIAMETER—CUT THREAD

0-12 inclusive. Minimum—Basic +0.0005.

Maximum

0-3 inclusive Minimum +0.0010
4-12 inclusive Minimum +0.0015

PITCH-DIAMETER—GROUND THREAD

6-12 inclusive. Minimum—Basic +0.0005
6-12 inclusive. Maximum—Minimum +0.0005

Method of measurement for pitch-diameter for all taps shall be by wire system and at teh first full thread

MAJOR DIAMETER—CUT THREAD

0-12 inclusive. Maximum—Basic $+0.01\sqrt{D}$

Minimum

0-3 inclusive. Maximum −0.0015
4-12 inclusive. Maximum −0.0020

MAJOR DIAMETER—GROUND THREAD

6-12 inclusive. Maximum—Basic +45 per cent truncation
6-12 inclusive. Minimum—Maximum Major −0.0015

OVER-ALL LENGTH—*A*

0-12 inclusive. ±1/32

THREAD LENGTH—*B*

0-12 inclusive. ±3/64

SQUARE LENGTH—*C*

0-12 inclusive. ±1/32

SHANK DIAMETER—*D*—CUT THREAD

0-12 inclusive. +0 −0.004

SHANK DIAMETER—*D*—GROUND THREAD

6-12 inclusive. +0 −0.0015

SQUARE SIZE—*E*

0-12 inclusive. +0 −0.0040

LAND WIDTH—*F*

8-12 inclusive. Included Angle—30 Deg.
8-12 inclusive. Size ±0.0075

CENTERS

0-12 inclusive. Thread end male

NUMBER OF FLUTES

0-6 inclusive. Three
8-12 inclusive. Four

CHAMFER

Four to six threads

MINOR DIAMETER

American (National) form or sharper

THREAD ANGLE—CUT THREAD

Tolerance in half angle
24-28 Threads ±45 min.
32-80 Threads ±60 min.
Total Error in Full Angle
24-28 Threads 68 min.
32-80 Threads 90 min.

LEAD ERROR—CUT THREAD

±0.0030 per inch of thread

LEAD ERROR—GROUND THREAD

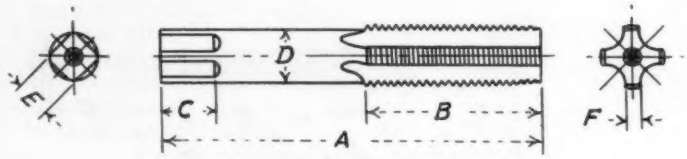
±0.0005 per inch of thread

RELIEF—CUT THREAD

Back Taper—Manufacturer's practice; slight eccentric relief permissible

RELIEF—GROUND THREAD

Back Taper—0.0005 to 0.0010 per inch; slight eccentric relief permissible



HAND PLUG TAPS—CUT THREADS

Size	Pitch-Diameter			Major Diameter			General Dimensions					
	Basic	Minimum	Maximum	Basic	Minimum	Maximum	Over-All Length, *A*	Thread Length, *B*	Square Length, *C*	Shank Diameter, *D*	Square Size, *E*	Land Width, *F*
1/4 -20	0.2175	0.2180	0.2200	0.2500	0.2525	0.2550	2 1/2	1	9/32	0.2550	0.1910	0.0650
1/4 -28	0.2268	0.2273	0.2288	0.2500	0.2525	0.2550	2 1/2	1	9/32	0.2550	0.1910	0.0650
5/16-18	0.2764	0.2769	0.2789	0.3125	0.3155	0.3180	2 23/32	1 1/8	5/16	0.3180	0.2380	0.0810
5/16-24	0.2854	0.2859	0.2874	0.3125	0.3155	0.3180	2 23/32	1 1/8	5/16	0.3180	0.2380	0.0810
3/8 -16	0.3344	0.3349	0.3369	0.3750	0.3785	0.3810	2 15/16	1 1/4	3/8	0.2750[a]	0.2060	0.0970
3/8 -24	0.3479	0.3484	0.3499	0.3750	0.3785	0.3810	2 15/16	1 1/4	3/8	0.3810[a]	0.2860	0.0970
7/16-14	0.3911	0.3916	0.3941	0.4375	0.4410	0.4440	3 5/32	1 7/16	13/32	0.3230	0.2420	0.1140
7/16-20	0.4050	0.4055	0.4075	0.4375	0.4410	0.4440	3 5/32	1 7/16	13/32	0.3230	0.2420	0.1140
1/2 -13	0.4500	0.4505	0.4530	0.5000	0.5040	0.5070	3 3/8	1 21/32	7/16	0.3670	0.2750	0.1300
1/2 -20	0.4675	0.4680	0.4700	0.5000	0.5040	0.5070	3 3/8	1 21/32	7/16	0.3670	0.2750	0.1300
9/16-12	0.5084	0.5089	0.5114	0.5625	0.5670	0.5700	3 19/32	1 21/32	1/2	0.4290	0.3220	0.1460
9/16-18	0.5264	0.5269	0.5289	0.5625	0.5670	0.5700	3 19/32	1 21/32	1/2	0.4290	0.3220	0.1460
5/8 -11	0.5660	0.5665	0.5690	0.6250	0.6300	0.6330	3 13/16	1 13/16	9/16	0.4800	0.3600	0.1620
5/8 -18	0.5889	0.5894	0.5914	0.6250	0.6300	0.6330	3 13/16	1 13/16	9/16	0.4800	0.3600	0.1620
3/4 -10	0.6850	0.6855	0.6885	0.7500	0.7550	0.7590	4 1/4	2	11/16	0.5900	0.4420	0.1940
3/4 -16	0.7094	0.7099	0.7124	0.7500	0.7550	0.7590	4 1/4	2	11/16	0.5900	0.4420	0.1940
7/8 -9	0.8028	0.8038	0.8068	0.8750	0.8805	0.8845	4 11/16	2 7/32	3/4	0.6970	0.5230	0.2120
7/8 -14	0.8286	0.8296	0.8321	0.8750	0.8805	0.8845	4 11/16	2 7/32	3/4	0.6970	0.5230	0.2120
1 -8	0.9188	0.9198	0.9228	1.0000	1.0060	1.0100	5 1/8	2 1/2	13/16	0.8000	0.6000	0.2420
1 -14	0.9536	0.9546	0.9571	1.0000	1.0060	1.0100	5 1/8	2 1/2	13/16	0.8000	0.6000	0.2420
1 1/8 -7	1.0322	1.0332	1.0367	1.1250	1.1310	1.1355	5 7/16	2 9/16	7/8	0.8960	0.6720	......
1 1/8 -12	1.0709	1.0719	1.0749	1.1250	1.1310	1.1355	5 7/16	2 9/16	7/8	0.8960	0.6720	......
1 1/4 -7	1.1572	1.1582	1.1617	1.2500	1.2565	1.2610	5 3/4	2 9/16	1	1.0210	0.7660	......
1 1/4 -12	1.1959	1.1969	1.1999	1.2500	1.2565	1.2610	5 3/4	2 9/16	1	1.0210	0.7660	......
1 1/2 -6	1.3917	1.3927	1.3962	1.5000	1.5075	1.5120	6 3/8	3	1 1/8	1.2330	0.9250	......
1 1/2 -12	1.4459	1.4469	1.4499	1.5000	1.5075	1.5120	6 3/8	3	1 1/8	1.2330	0.9250	......

[a]Optional shank diameters.

GENERAL SPECIFICATIONS

PITCH-DIAMETER

Minimum
1/4-3/4 inclusive. Basic +0.0005
7/8-1 1/2 inclusive. Basic +0.0010

Maximum

		Fine Thread	Coarse Thread
1/4-3/8 inclusive.	Minimum	+0.0015	+0.0020
7/16-5/8 inclusive.	Minimum	+0.0020	+0.0025
3/4-1 inclusive.	Minimum	+0.0025	+0.0030
1 1/8-1 1/2 inclusive.	Minimum	+0.0030	+0.0035

Method of measurement for pitch-diameter for all taps shall be by wire system and at the first full thread

MAJOR DIAMETER

1/4-1 1/2 inclusive. Maximum—Basic +0.01 $\sqrt{D}$

Minimum
1/4-3/8 inclusive. Maximum −0.0025
7/16-5/8 inclusive. Maximum −0.0030
3/4-1 inclusive. Maximum −0.0040
1 1/8-1 1/2 inclusive. Maximum −0.0045

OVER-ALL LENGTH—*A*

1/4-1 inclusive. ±1/32
1 1/8-1 1/2 inclusive. ±1/16

THREAD LENGTH—*B*

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

SQUARE LENGTH—*C*

1/4-5/8 inclusive. ±1/32
3/4-1 1/2 inclusive. ±1/16

SHANK DIAMETER—*D*

1/4-1 inclusive. +0.0000 −0.0050
1 1/8-1 1/2 inclusive. +0.0000 −0.0070

SQUARE SIZE—*E*

1/4-1/2 inclusive. +0.0000 −0.0040
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

LAND WIDTH—*F*

1/4-3/4 inclusive. Included Angle—30 Deg.
7/8-1 inclusive. Included Angle—28 Deg.
1/4-1 inclusive. Size ±0.0100

CENTERS

1/4-5/16 inclusive. Thread end male
3/8-1 1/2 inclusive. Female

NUMBER OF FLUTES

Four

CHAMFER

Three to five threads

MINOR DIAMETER

American (National) form or sharper

THREAD ANGLE

Tolerance in half Angle
6-9 Threads. ±40 min.
10-28 Threads. ±45 min.
Total Error in Full Angle
6-9 Threads. 60 min.
10-28 Threads. 68 min.

LEAD ERROR

±0.003 per inch of thread

RELIEF

Back Taper—Manufacturer's practice; slight eccentric relief permissible.

HAND PLUG TAPS—GROUND THREADS

Size	Pitch-Diameter			Major Diameter			General Dimensions					
	Basic	Minimum	Maximum	Basic	Minimum	Maximum	Over-All Length, *A*	Thread Length, *B*	Square Length, *C*	Shank Diameter, *D*	Square Size, *E*	Land Width, *F*
1/4 -20	0.2175	0.2180	0.2185	0.2500	0.2535	0.2550	2 1/2	1	9/32	0.2550	0.1910	0.0650
1/4 -28	0.2268	0.2273	0.2278	0.2500	0.2520	0.2535	2 1/2	1	9/32	0.2550	0.1910	0.0650
5/16-18	0.2764	0.2769	0.2774	0.3125	0.3165	0.3180	2 23/32	1 1/8	5/16	0.3180	0.2380	0.0810
5/16-24	0.2854	0.2859	0.2864	0.3125	0.3150	0.3165	2 23/32	1 1/8	5/16	0.3180	0.2380	0.0810
3/8 -16	0.3344	0.3349	0.3354	0.3750	0.3795	0.3810	2 15/16	1 1/4	3/8	0.2750[a]	0.2060	0.0970
3/8 -24	0.3479	0.3484	0.3489	0.3750	0.3775	0.3790	2 15/16	1 1/4	3/8	0.3810[a]	0.2860	0.0970
7/16-14	0.3911	0.3916	0.3921	0.4375	0.4425	0.4440	3 5/32	1 7/16	13/32	0.3230	0.2420	0.1140
7/16-20	0.4050	0.4055	0.4060	0.4375	0.4410	0.4425	3 5/32	1 7/16	13/32	0.3230	0.2420	0.1140
1/2 -13	0.4500	0.4505	0.4510	0.5000	0.5055	0.5070	3 3/8	1 21/32	7/16	0.3670	0.2750	0.1300
1/2 -20	0.4675	0.4680	0.4685	0.5000	0.5035	0.5050	3 3/8	1 21/32	7/16	0.3670	0.2750	0.1300
9/16-12	0.5084	0.5089	0.5094	0.5625	0.5685	0.5700	3 19/32	1 21/32	1/2	0.4290	0.3220	0.1460
9/16-18	0.5264	0.5269	0.5274	0.5625	0.5665	0.5680	3 19/32	1 21/32	1/2	0.4290	0.3220	0.1460
5/8 -11	0.5660	0.5665	0.5676	0.6250	0.6315	0.6330	3 13/16	1 13/16	9/16	0.4800	0.3600	0.1620
5/8 -18	0.5889	0.5894	0.5902	0.6250	0.6290	0.6305	3 13/16	1 13/16	9/16	0.4800	0.3600	0.1620
3/4 -10	0.6850	0.6855	0.6866	0.7500	0.7570	0.7590	4 1/4	2	11/16	0.5900	0.4420	0.1940
3/4 -16	0.7094	0.7099	0.7107	0.7500	0.7540	0.7560	4 1/4	2	11/16	0.5900	0.4420	0.1940
7/8 -9	0.8028	0.8038	0.8050	0.8750	0.8830	0.8850	4 11/16	2 7/32	3/4	0.6970	0.5230	0.2120
7/8 -14	0.8286	0.8296	0.8305	0.8750	0.8795	0.8815	4 11/16	2 7/32	3/4	0.6970	0.5230	0.2120
1 -8	0.9188	0.9198	0.9212	1.0000	1.0090	1.0110	5 1/8	2 1/2	13/16	0.8000	0.6000	0.2420
1 -14	0.9536	0.9546	0.9555	1.0000	1.0045	1.0065	5 1/8	2 1/2	13/16	0.8000	0.6000	0.2420
1 1/8 -7	1.0322	1.0332	1.0347	1.1250	1.1345	1.1370	5 7/16	2 9/16	7/8	0.8960	0.6720	......
1 1/8 -12	1.0709	1.0719	1.0729	1.1250	1.1300	1.1325	5 7/16	2 9/16	7/8	0.8960	0.6720	......
1 1/4 -7	1.1572	1.1582	1.1597	1.2500	1.2595	1.2620	5 3/4	2 9/16	1	1.0210	0.7660	......
1 1/4 -12	1.1959	1.1969	1.1979	1.2500	1.2550	1.2575	5 3/4	2 9/16	1	1.0210	0.7660	......
1 1/2 -6	1.3917	1.3927	1.3945	1.5000	1.5115	1.5140	6 3/8	3	1 1/8	1.2330	0.9250	......
1 1/2 -12	1.4459	1.4469	1.4479	1.5000	1.5050	1.5075	6 3/8	3	1 1/8	1.2330	0.9250	......

[a]Optional shank diameters.

GENERAL SPECIFICATIONS

PITCH-DIAMETER

Minimum
1/4-3/4 inclusive Basic +0.0005
7/8-1 1/2 inclusive. Basic +0.0010

Maximum
1/4-9/16 inclusive. Minimum +0.0005
5/8-1 1/2 inclusive. Minimum +25 per cent of American (National) Standard Class 3 tolerance

Method of measurement for pitch-diameter for all taps shall be by wire system and at the first full thread

MAJOR DIAMETER

Maximum
6-12 Threads. Basic +40 per cent truncation
13-32 Threads. Basic +45 per cent truncation

Minimum
1/4-5/8 inclusive. Maximum major—0.0015
3/4-1 inclusive. Maximum major—0.0020
1 1/8-1 1/2 inclusive. Maximum major—0.0025

OVER-ALL LENGTH—*A*

1/4-1 inclusive. ±1/32
1 1/8-1 1/2 inclusive. ±1/16

THREAD LENGTH—*B*

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

SQUARE LENGTH—*C*

1/4-5/8 inclusive. ±1/32
3/4-1 1/2 inclusive. ±1/16

SHANK DIAMETER—*D*

1/4-5/8 inclusive. +0.0000 −0.0015
3/4-1 1/2 inclusive. +0.0000 −0.0020

SQUARE SIZE—*E*

1/4-1/2 inclusive. +0.0000 −0.0040
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

LAND WIDTH—*F*

1/4-3/4 inclusive. Included Angle—30 Deg.
7/8-1 inclusive. Included Angle—28 Deg.
1/4-1 inclusive. Size ±0.0100

CENTERS

Female

NUMBER OF FLUTES

Four

CHAMFER

Three to four threads

MINOR DIAMETER

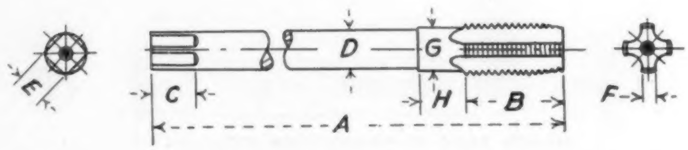
American (National) form or sharper

LEAD ERROR

±0.0005 per inch of thread

RELIEF

Back Taper—0.0005 to 0.0010 per inch; slight eccentric relief permissible



TAPPER TAPS—GROUND THREADS

Size	Pitch-Diameter			Major Diameter			General Dimensions							
	Basic	Minimum	Maximum	Basic	Minimum	Maximum	Over-All Length, *A*[1]	Thread Length, *B*	Square Length, *C*	Shank Diameter, *D*	Square Size, *E*	Land Width, *F*	Pilot Diameter, *G*	Pilot Length, *H*
1/4 -20	0.2175	0.2180	0.2185	0.2500	0.2535	0.2550	12	1 1/4	9/16	0.1850	0.1390	0.0650	......	....
1/4 -28	0.2268	0.2273	0.2278	0.2500	0.2520	0.2535	15	1	9/16	0.1850	0.1390	0.0650	0.2035	1/4
5/16-18	0.2764	0.2769	0.2774	0.3125	0.3165	0.3180	12	1 3/8	5/8	0.2400	0.1800	0.0810	......	....
5/16-24	0.2854	0.2859	0.2864	0.3125	0.3150	0.3165	15	1 1/16	5/8	0.2400	0.1800	0.0810	0.2585	5/16
3/8 -16	0.3344	0.3349	0.3354	0.3750	0.3795	0.3810	12	1 9/16	11/16	0.2940	0.2200	0.0970	......	....
3/8 -24	0.3479	0.3484	0.3489	0.3750	0.3775	0.3790	15	1 3/16	11/16	0.2940	0.2200	0.0970	0.3210	3/8
7/16-14	0.3911	0.3916	0.3921	0.4375	0.4425	0.4440	12	1 13/16	3/4	0.3450	0.2590	0.1140	......	....
7/16-20	0.4050	0.4055	0.4060	0.4375	0.4410	0.4425	15	1 3/8	3/4	0.3450	0.2590	0.1140	0.3725	7/16
1/2 -13	0.4500	0.4505	0.4510	0.5000	0.5055	0.5070	12	1 7/8	7/8	0.4000	0.3000	0.1300	......	....
1/2 -20	0.4675	0.4680	0.4685	0.5000	0.5035	0.5050	15	1 3/8	7/8	0.4000	0.3000	0.1300	0.4350	1/2
9/16-12	0.5084	0.5089	0.5094	0.5625	0.5685	0.5700	12	2 1/8	7/8	0.4500	0.3370	0.1460	......	....
9/16-18	0.5264	0.5269	0.5274	0.5625	0.5665	0.5680	15	1 9/16	7/8	0.4500	0.3370	0.1460	0.4905	9/16
5/8 -11	0.5660	0.5665	0.5676	0.6250	0.6315	0.6330	12	2 5/16	15/16	0.5030	0.3770	0.1620	......	....
5/8 -18	0.5889	0.5894	0.5902	0.6250	0.6290	0.6305	15	1 11/16	15/16	0.5030	0.3770	0.1620	0.5530	5/8
3/4 -10	0.6850	0.6855	0.6866	0.7500	0.7570	0.7590	12	2 1/2	1	0.6160	0.4620	0.1940	......	....
3/4 -16	0.7094	0.7099	0.7107	0.7500	0.7540	0.7560	15	1 3/4	1	0.6160	0.4620	0.1940	0.6690	3/4
7/8 -9	0.8028	0.8038	0.8050	0.8750	0.8830	0.8850	12	2 3/4	1 1/16	0.7270	0.5450	0.2120	......	....
7/8 -14	0.8268	0.8296	0.8305	0.8750	0.8795	0.8815	15	1 7/8	1 1/16	0.7270	0.5450	0.2120	0.7820	7/8
1 -8	0.9188	0.9198	0.9212	1.0000	1.0090	1.0110	12	3 1/8	1 1/8	0.8340	0.6250	0.2420	......	....
1 -14	0.9536	0.9546	0.9555	1.0000	1.0045	1.0065	15	2 1/8	1 1/8	0.8340	0.6250	0.2420	0.9070	1
1 1/8 -7	1.0322	1.0332	1.0347	1.1250	1.1345	1.1370	15	3 1/2	1 1/4	0.9330	0.7000	......	......	....
1 1/8 -12	1.0709	1.0719	1.0729	1.1250	1.1300	1.1325	15	2 3/8	1 1/4	0.9330	0.7000	......	1.0170	1 1/8
1 1/4 -7	1.1572	1.1582	1.1597	1.2500	1.2595	1.2620	15	3 1/2	1 5/16	1.0580	0.7930	......	......	....
1 1/4 -12	1.1959	1.1969	1.1979	1.2500	1.2550	1.2575	15	2 3/8	1 5/16	1.0580	0.7930	......	1.1420	1 1/8
1 1/2 -6	1.3917	1.3927	1.3945	1.5000	1.5115	1.5140	15	4	1 1/2	1.2780	0.9580	......	......	....
1 1/2 -12	1.4459	1.4469	1.4479	1.5000	1.5050	1.5075	15	2 5/8	1 1/2	1.2780	0.9580	......	1.3920	1 3/8

[1] Optional over-all lengths.

GENERAL SPECIFICATIONS

PITCH-DIAMETER

Minimum

1/4-3/4 inclusive. Basic +0.0005
7/8-1 1/2 inclusive. Basic +0.0010

Maximum

1/4-9/16 inclusive. Minimum +0.0005
5/8-1 1/2 inclusive. Minimum +25 per cent of American (National) Standard Class 3 tolerance

Method of measurement for pitch-diameter for all taps shall be wire system and at the first full thread

MAJOR DIAMETER

Maximum

6-12 Threads Basic +40 per cent truncation
13-32 Threads Basic +45 per cent truncation

Minimum

1/4-5/8 inclusive. Maximum Major −0.0015
3/4-1 inclusive. Maximum Major −0.0020
1 1/8-1 1/2 inclusive. Maximum Major −0.0025

OVER-ALL LENGTH—*A*

1/4-1 inclusive. ±1/8
1 1/8-1 1/2 inclusive. ±3/16

THREAD LENGTH—*B*

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

SQUARE LENGTH—*C*

1/4-5/8 inclusive. ±1/32
3/4-1 1/2 inclusive. ±1/16

SHANK DIAMETER—*D*

1/4-1/2 inclusive. +0.0000 −0.0050
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

SQUARE SIZE—*E*

1/4-1/2 inclusive. +0.0000 −0.0040
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

LAND WIDTH—*F*

1/4-3/4 inclusive. Included Angle—30 Deg.
7/8-1 inclusive. Included Angle—28 Deg.
1/4-1 inclusive. Size ±0.0100

PILOT DIAMETER-*G*—FINE THREADS

1/4-1 1/2 inclusive. Minor diameter
1/4-1 1/2 inclusive. Size +0.0000 −0.0050

PILOT LENGTH-*H*—FINE THREADS

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

CENTERS

Female

NUMBER OF FLUTES

Four

CHAMFER

Coarse Threads Chamfer 11 to 12 threads
Fine Threads Chamfer 15 to 17 threads

MINOR DIAMETER

American (National) form or sharper

LEAD ERROR

±0.0005 per inch of thread

RELIEF

Back Taper—0.0005 to 0.0010 per inch
1/4-3/8 inclusive. Slight eccentric relief permissible
7/16-1 1/2 inclusive. Eccentric relief required

TAPPER TAPS—CUT THREADS

Size	Pitch-Diameter			Major Diameter			General Dimensions							
	Basic	Minimum	Maximum	Basic	Minimum	Maximum	Over-All Length, A[2]	Thread Length, B	Square Length, C	Shank Diameter, D	Square Size, E	Land Width, F	Pilot Diameter, G	Pilot Length, H
1/4 -20	0.2175	0.2180	0.2200	0.2500	0.2525	0.2550	12	1 1/4	9/16	0.1850	0.1390	......	......	....
1/4 -28	0.2268	0.2273	0.2288	0.2500	0.2525	0.2550	15	1	9/16	0.1850	0.1390	......	0.2035	1/4
5/16-18	0.2764	0.2769	0.2789	0.3125	0.3155	0.3180	12	1 3/8	5/8	0.2400	0.1800	......	......	....
5/16-24	0.2854	0.2859	0.2874	0.3125	0.3155	0.3180	15	1 1/16	5/8	0.2400	0.1800	......	0.2585	5/16
3/8 -16	0.3344	0.3349	0.3369	0.3750	0.3785	0.3810	12	1 9/16	11/16	0.2940	0.2200	......	......	....
3/8 -24	0.3479	0.3484	0.3499	0.3750	0.3785	0.3810	15	1 3/16	11/16	0.2940	0.2200	......	0.3210	3/8
7/16-14	0.3911	0.3916	0.3941	0.4375	0.4410	0.4440	12	1 13/16	3/4	0.3450	0.2590	......	......	....
7/16-20	0.4050	0.4055	0.4075	0.4375	0.4410	0.4440	15	1 3/8	3/4	0.3450	0.2590	......	0.3725	7/16
1/2 -13	0.4500	0.4505	0.4530	0.5000	0.5040	0.5070	12	1 7/8	7/8	0.4000	0.3000	......	......	....
1/2 -20	0.4675	0.4680	0.4700	0.5000	0.5040	0.5070	15	1 3/8	7/8	0.4000	0.3000	......	0.4350	1/2
9/16-12	0.5084	0.5089	0.5114	0.5625	0.5670	0.5700	12	2 1/8	7/8	0.4500	0.3370	......	......	....
9/16-18	0.5264	0.5269	0.5289	0.5625	0.5670	0.5700	15	1 9/16	7/8	0.4500	0.3370	......	0.4905	9/16
5/8 -11	0.5660	0.5665	0.5690	0.6250	0.6300	0.6330	12	2 5/16	15/16	0.5030	0.3770	......	......	....
5/8 -18	0.5889	0.5894	0.5914	0.6250	0.6300	0.6330	15	1 11/16	15/16	0.5030	0.3770	......	0.5530	5/8
3/4 -10	0.6850	0.6855	0.6885	0.7500	0.7550	0.7590	12	2 1/2	1	0.6160	0.4620	0.1940	......	....
3/4 -16	0.7094	0.7099	0.7124	0.7500	0.7550	0.7590	15	1 3/4	1	0.6160	0.4620	0.1940	0.6690	3/4
7/8 -9	0.8028	0.8038	0.8068	0.8750	0.8805	0.8845	12	2 3/4	1 1/16	0.7270	0.5450	0.2120	......	....
7/8 -14	0.8286	0.8296	0.8321	0.8750	0.8805	0.8845	15	1 7/8	1 1/16	0.7270	0.5450	0.2120	0.7820	7/8
1 -8	0.9188	0.9198	0.9228	1.0000	1.0060	1.0100	12	3 1/8	1 1/8	0.8340	0.6250	0.2420	......	....
1 -14	0.9536	0.9546	0.9571	1.0000	1.0060	1.0100	15	2 1/8	1 1/8	0.8340	0.6250	0.2420	0.9070	1
1 1/8 -7	1.0322	1.0332	1.0367	1.1250	1.1310	1.1355	15	3 1/2	1 1/4	0.9330	0.7000	......	......	....
1 1/8 -12	1.0709	1.0719	1.0749	1.1250	1.1310	1.1355	15	2 3/8	1 1/4	0.9330	0.7000	......	1.0170	1 1/8
1 1/4 -7	1.1572	1.1582	1.1617	1.2500	1.2565	1.2610	15	3 1/2	1 5/16	1.0580	0.7930	......	......	....
1 1/4 -12	1.1959	1.1969	1.1999	1.2500	1.2565	1.2610	15	2 3/8	1 5/16	1.0580	0.7930	......	1.1420	1 1/8
1 1/2 -6	1.3917	1.3927	1.3962	1.5000	1.5075	1.5120	15	4	1 1/2	1.2780	0.9580	......	......	....
1 1/2 -12	1.4459	1.4469	1.4499	1.5000	1.5075	1.5120	15	2 5/8	1 1/2	1.2780	0.9580	......	1.3920	1 3/8

[2]Optional over-all lengths.

GENERAL SPECIFICATIONS

PITCH-DIAMETER

	Minimum	
1/4-3/4 inclusive.	Basic +0.0005	
7/8-1 1/2 inclusive.	Basic +0.0010	
	Maximum	
	Fine Thread	Coarse Thread
1/4-3/8 inclusive.	Minimum +0.0015	+0.0020
7/16-5/8 inclusive.	Minimum +0.0020	+0.0025
3/4-1 inclusive.	Minimum +0.0025	+0.0030
1 1/8-1 1/2 inclusive.	Minimum +0.0030	+0.0035

Method of measurement for pitch-diameter for all taps shall be by wire system and at the first full thread

MAJOR DIAMETER

1/4-1 1/2 inclusive. Maximum—Basic $+0.01\sqrt{D}$

Minimum

1/4-3/8 inclusive. Maximum −0.0025
7/16-5/8 inclusive. Maximum −0.0030
3/4-1 inclusive. Maximum −0.0040
1 1/8-1 1/2 inclusive. Maximum −0.0045

OVER-ALL LENGTH—*A*

1/4-1 inclusive. ±1/8
1 1/8-1 1/2 inclusive. ±3/16

THREAD LENGTH—*B*

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

SQUARE LENGTH—*C*

1/4-5/8 inclusive. ±1/32
3/4-1 1/2 inclusive. ±1/16

SHANK DIAMETER—*D*

1/4-1/2 inclusive. +0.0000 −0.0050
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

SQUARE SIZE—*E*

1/4-1/2 inclusive. +0.0000 −0.0040
9/16-1 inclusive. +0.0000 −0.0060
1 1/8-1 1/2 inclusive. +0.0000 −0.0080

LAND WIDTH—*F*

1/4-5/8 inclusive. Manufacturer's standard
3/4 Included Angle—30 Deg.
7/8-1 inclusive. Included Angle—28 Deg.
3/4-1 inclusive. Size ±0.0100

PILOT DIAMETER—*G*—FINE THREAD

1/4-1 1/2 inclusive. Minor diameter
1/4-1 1/2 inclusive. Size +0.0000 −0.0050

PILOT LENGTH—*H*—FINE THREADS

1/4-1/2 inclusive. ±1/16
9/16-1 1/2 inclusive. ±3/32

CENTERS

1/4-3/8 inclusive. Thread end male
7/16-1 1/2 inclusive. Female

NUMBER OF FLUTES

1/4-5/8 inclusive. Three
3/4-1 1/2 inclusive. Four

CHAMFER

Coarse Threads Chamfer 11 to 12 threads
Fine Threads Chamfer 15 to 17 threads

MINOR DIAMETER

American (National) form or sharper

THREAD ANGLE

Tolerance in half Angle
6-9 Threads ±40 min.
10-28 Threads ±45 min.
Total Error in Full Angle
6-9 Threads 60 min.
10-28 Threads 68 min.

LEAD ERROR

±0.003 per inch of thread

RELIEF

Back Taper—Manufacturer's standard
1/4—3/8 inclusive. Slight eccentric relief permissible
7/16-1 1/2 inclusive. Eccentric relief required

W. J. O'Neil	Chrysler Corporation
F. W. Stein	Fairbanks, Morse & Co.
James Thiel	Waukesha Motor Co.
E. K. Wennerlund	General Motors Corporation

CUT AND GROUND TAP STANDARD APPROVED

History of Development and Expected Results Concisely Presented by D. W. Ovaitt

In order that the Society may be fully apprised of the need for standardization of taps, D. W. Ovaitt, of the Buick Motor Car Co., has supplemented his report by an article briefly outlining the development and results obtained by the setting of the proposed specifications.

Mr. Ovaitt, who is chairman of the subcommittee on taps and gages of the Works Managers' Committee of the General Motors Corporation and a member of the Screw-Threads Division of the Standards Committee, has developed the accompanying specifications after an exhaustive investigation involving the measurement of hundreds of holes. The resultant tap standards have been approved by the leading tap and die manufacturers of the Country and will be followed by them in the future.

The Screw-Threads and Production Divisions, at a joint meeting in Detroit on April 22, approved this report and recommend its adoption as an S.A.E. Standard. Mr. Ovaitt's article follows:

CUT AND GROUND TAPS

The problem of producing internal threads accurately has confronted production engineers since the time when interchangeability of parts became a necessity in mass production. The conventional method of producing threaded holes has been to use a type of tool known as a tap. The first taps were more or less crude in design, and undoubtedly the product was worse. Demands by engineers for more accuracy and better fit of thread between mating parts has been responsible for some wonderful changes in the methods of producing taps.

Ground-thread taps came into being in the art of producing taps only a comparatively short time ago. This probably had more to do with producing accurate threaded holes than any other one development since taps were first used.

Unfortunately, the various manufacturers of taps, with either cut or ground threads, had different ideas as to what the pitch-diameter of taps should be. This condition probably resulted from varying demands by customers for taps which would, in the absence of recognized standards, produce fits in mating parts to their requirements. Such general conditions frequently preclude the possibility of threaded parts being interchangeable between different manufacturing institutions. In a company such as the General Motors Corporation it frequently happens that the parts produced in one subsidiary company should interchange with parts produced by another, and it is, therefore, obvious that standards, both as to the threaded holes and taps, should be established to accomplish this purpose. The National Screw Thread Commission, in cooperation with the various screw and nut producers throughout the Country, has set up certain standards on both these commodities, which has made it possible to select one class of tolerances that is quite acceptable for our closest fit requirements.

A series of experiments was then made involving hundreds of holes in all popular sizes to determine how much a tap would actually cut oversize. With such data available, it was practicable to establish one set of tap pitch-diameters which would under normal shop-conditions produce holes within the class of tolerances selected. It seemed that several features of tap construction other than the pitch-diameter should be given consideration in establishing the standards. Negotiations were opened with the various tap-manufacturers and in the several meetings that followed, the tap standards which appear in the accompanying tables were adopted. Considerable credit for this work is due J. Chester Bath and H. C. Hungerford, representing the tap manufacturers, and their excellent cooperation in assisting to establish these standards.

The benefits to be derived through the universal adoption of these tap standards may be summarized as follows:

(1) One standard for pitch-diameters to produce Class-3 tolerances in the majority of cases and always within Class-2 tolerances

(2) New standards for major-diameters for all classes of tap resulting in considerable increase in the number of holes produced per tap

(3) A new standard for general tap dimensions, which assures a more-uniform product from all tap manufacturers

(4) A new standard with smaller tolerances on tap-construction dimensions; which assures better and more uniform results

(5) A tapper-tap standard that has not heretofore existed, applying to all the tap dimensions. It is hoped that in time nut tapping-machine manufacturers will confine their machines to the same style of tap driver, as there are at present five recognized standards of tap driver on the market

(6) A much better understanding by tap manufacturers than has existed heretofore of the tap-users' problems and requirements

BALL AND ROLLER-BEARINGS DIVISION

PERSONNEL

H. E. Brunner, *Chairman*	S. K. F. Industries, Inc.
G. R. Bott, *Vice-Chairman*	Norma-Hoffmann Bearings Corporation
F. L. Brown	White Motor Co.
T. V. Buckwalter	Timken Roller Bearing Co.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
L. A. Cummings	Marlin-Rockwell Corporation
B. H. Gilpin	H. H. Franklin Mfg. Co.
F. W. Gurney	Marlin-Rockwell Corporation
F. G. Hughes	New Departure Mfg. Co.
H. N. Parsons	Strom Bearings Co.
W. R. Strickland	Cadillac Motor Car Co.

ROLLER-BEARINGS STANDARD REVISION

Division Proposes Additional Sizes in Two Series and Eliminations in Four

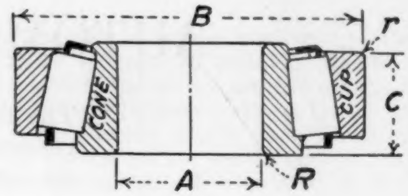
At the time this report was prepared for printing in this issue of THE JOURNAL, the Ball and Roller-Bearings Division was balloting by letter on the proposed change in the present S.A.E. Standard for Roller-Bearings printed on p. C31 of the S.A.E. HANDBOOK. The report is published herewith so that it can be presented at the Standards Committee Meeting of the Society on May 25 for disposition with other reports of Divisions to the Standards Committee.

The proposed revisions were submitted by Ernest Wooler,

of the Timken Roller Bearing Co., to bring the standard up-todate. It is proposed that the following sizes be discontinued inasmuch as their use has not been recommended since the standard was adopted last year. The sizes will be found on pages C31e and C31f of the March, 1927, issue of the S.A.E. HANDBOOK.

2300 Series	2380 —2323
	2381 —2323
	2382 —2323
3300 Series	3379 —3320
	3381 —3320
	3381T—3320
	3382 —3320
	3382 —3320
	3382T—3320
6500 Series	6576 —6520
	6578 —6520
	6580 —6520
23000 Series	23092 —23256
	23111 —23256

Mr. Wooler has also reported two new series of bearings that have been developed to fill in a gap in the present standard and has submitted the following for adoption in the standard.



Bearing Number	*A*	*B*	*C*	*R*	*r*
		525 Series			
525-522	1.500	4.00	1 3/8	9/64	1/8
526-522	1.625	4.00	1 3/8	9/64	1/8
527-522	1.750	4.00	1 3/8	9/64	1/8
528-522	1.875	4.00	1 3/8	9/64	1/8
529-522	2.000	4.00	1 3/8	1/32	1/8
		6200 Series			
6277-6220	1.750	5.00	2.00	9/64	1/8
6279-6220	2.000	5.00	2.00	9/64	1/8
6280-6220	2.125	5.00	2.00	9/64	1/8

There are a few other slight changes such as in corner radius of some bearings that have been worked out and will be reported at the meeting of the Standards Committee on May 25.

ACTIVITIES OF THE SECTIONS

(*Continued from p.* 540)

fied variously in each State and operating under greatly differing legislative powers. Without machinery for joint action between these many administrative units, it is difficult if not impossible to carry out major development projects. The physical problems of the region do not align themselves with its political boundaries, and the population spreads without regard for them. Highways and other improvements also accompany an increasing population.

Indirect, broken, incomplete, and poorly marked by-pass motor-car routes now force a tremendous volume of unnecessary motor-vehicle traffic to flow into and through the congested centers of the larger cities of the Tri-State District, particularly Philadelphia and Camden. Mr. Wetherill said that new ways around the congested centers must be provided in all directions and that present routes must be completed and improved to carry the increasing through traffic and to meet the certain demands of the future. He stated that these new highways, many of them in all probability forced through open farm-land to avoid costly destruction of existing improvements, will become large factors in the orderly progress of the region.

Early travelers in their journeys from home to market largely determined the present highway system of the Tri-State District. All travel being to and from the central city, highways were built from all points of the compass toward the center, resulting in the present excellent fan-shaped system of radial roads, now great trunk highways carrying immense traffic in and out. But not until much later and until the country was further developed did intercourse between the outlying towns justify the building of cross-connecting roads. Then, the later roads, built around the center a link at a time, were irregular, disconnected and inadequate.

Mr. Wetherill said further that this entire system of highways must be built up and improved to meet new and changing demands. Great express and freight highways are an impending necessity. In his opinion, highways must no longer be permitted simply to "grow." but must be designed expressly for the purpose which they are to serve; that is, as residential, business or main thoroughfares. But the speaker said that to build up an adequate system of roads in such a district is now no easy task, since it is no longer a matter of blazing a trail and clearing a way through the wilderness. However, he said that the only way to extensive accomplishment is to take advantage of inevitable growth, to plan new highways far ahead of spreading population and to allow expansion to absorb them.

TRAFFIC CONDITIONS IN CHICAGO

Recent Traffic-Control-Improvement Features Discussed by Chicago Section

CARROLL E. ROBB

Betterment of traffic conditions in Chicago was the subject treated by Carroll E. Robb of the National Safety Council, in his paper on Traffic Problems and Their Solution. The paper was presented at the meeting of the Chicago Section that was held April 12 at the headquarters of the Western Society of Engineers in that city. O. W. Young presided as chairman at the technical session.

Early in the presentation of his paper Mr. Robb quoted from the report of the metropolitan street-traffic survey in Chicago to the effect that speed in itself is never dangerous. Accidents result from speed plus unfavorable factors to be found in the condition of the operator, and that of the vehicle, the roadway and other traffic. Unfortunately, it is impossible to leave a decision of these conditions to individual drivers, and set speed-limits become necessary for the restraint of those who lack judgment. He then went on to mention certain human factors which enter into the traffic situation to complicate it and to keep it from complying with laws and ordinances with any degree of certainty.

Like flowing water, the speaker said, flowing traffic can be restricted in its movements by obstructions, by roughnesses in its pathway, and by bottle necks or constrictions. It may be restricted further in its freedom and fluidity by ungoverned and uncontrolled speed of individuals who dodge in and out of the traffic stream, who drive on the wrong side of the road, who "hog" the road, and who do not observe the right-of-way rule, other rules of the road and ordinary courtesy. Irregularities in the curb line, too short a radius

(*Continued on p.* 619)

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

ULTRA-VIOLET SPECTROSCOPY

Elements of Motor-Fuel Spectroscopy and Application to Study of Detonation

Those fortunate individuals who attended the Research Session at the Annual Meeting were given an opportunity, through the introductory remarks of Dr. G. L. Clark[1] in the presentation of the paper on Ultra-violet Spectroscopy of Engine Fuel Flames by G. L. Clark and A. L. Henne,[2] to obtain an excellent conception of the elementary principles and *modus operandi* of the spectroscope as a scientific instrument in the study of detonation, explosion, and combustion-flame phenomena in engine cylinders; but the evidence is not lacking that there is still an imperfect understanding of the method and only partial appreciation of the significance of the results on the part of many interested but, perhaps, less fortunate students of combustion phenomena.

It was with the intention of serving the needs of such persons that the following article was prepared by Lieut. Walter C. Thee[3] and it is presented here with some realization of the necessity for engineers becoming familiar with, at least, the fundamentals and the terminology of modern physics if they are to pass on the benefits of the many momentous developments in contemporary science by performing their function of adapting them to industry and its processes.

The theoretical value of spectroscopy in the definitive study of the ultimate nature of matter is generally recognized and there is great expectation that this method of investigating the elusive problem of detonation may in its practical application lead to results of notable technical importance.

Nine or more theories of detonation and the action of detonation suppressers and inducers have been proposed. Some of these theories have been shown to be entirely erroneous, others are recognized as inadequate, the status of still others is not amenable to direct experimental determination by the heretofore customary laboratory methods, and there is no consensus of opinion that any one of these theories will prove sufficient to account for all elements of detonation and explain its control.

Among other things, the results so far obtained indicate that the spectra of combustion, explosion and detonation are different, the mechanism at various parts of the stroke and the changes with pressure have been segregated, certain characteristics of the spectra obtained with various inducers and suppressers of detonation have been clearly shown, and with these results the spectra in the ultra-violet region give great promise of successful experimental attack upon the whole mechanism of the reactions in internal-combustion engines, including the mechanism of detonation.

Lieutenant Thee was associated with Dr. Clark in the early spectroscopic investigations of the flames of motor fuels covering the three fundamental phenomena of combustion, explosion and detonation, at the Massachusetts Institute of Technology, and by scientific training and research experience is eminently qualified to explain the elementary principles of spectroscopy, show its application to studies of the characteristics of motor fuels and indicate the interpretation of the results and their significance—which is the purpose of the following.

[1] Divisional Director, research laboratory of applied chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Fellow of the Chemical Research Board Foundation, Massachusetts Institute of Technology, Cambridge, Mass.

[3] S.M.S.A.E.—Adjutant, Quartermaster Corps, Motor Transport School, Camp Holabird, Baltimore.

PAPER BY LIEUT. W. C. THEE

In reference to the ultra-violet spectroscopy of motor fuels, this method of studying detonation and detonation control is one of the most practical applications of a scientific subject. The apparatus consists of a single-cylinder experimental-engine equipped with a quartz window in the combustion-chamber and a spectroscope which is capable of photographing the spectra of the flames of various fuels used in the actual operation of an internal-combustion engine. Fig. 1 is a diagram of the optical system of the spectroscope. Before attempting to go any further, I will explain some fundamentals which will refresh the reader's knowledge on the theory of the prism and enable him to understand more readily what is to follow.

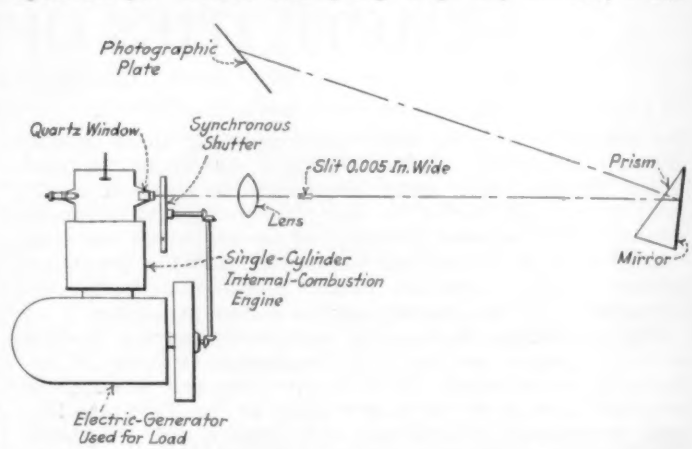


FIG. 1—DIAGRAM OF THE OPTICAL SYSTEM OF THE SPECTROSCOPE
The Apparatus Consists Essentially of a Single-Cylinder Internal-Combustion Engine with a Quartz Window Mounted in the Combustion-Chamber and a Photographic Quartz Spectrometer Consisting of the Following Synchronous Elements: Shutter, Lens, Slit, Prism, Mirror and Photographic Plate

THEORY OF THE PRISM

During the process of sending a ray of light through a prism, the incident ray, in passing through, undergoes a change in direction and the angular change can be found by prolonging the incident and the emergent rays. This blending, an example of which is shown in Fig. 2, is called refraction.

When a ray of light is refracted by passing from one medium to another, as from air into water, the angle contained between the incident ray and the normal at the point of incidence is called the angle of incidence and the angle contained between the refracted ray and its normal to the surface at the same point is called the angle of refraction. The ratio of the angle of incidence to the angle of refraction is a constant and is called the refractive index.

When a ray passes through a prism, refraction takes place at both the point of incidence and the point of emergence. The total deviation angle is equal to the sum of the two deviations. In Fig. 2, when angle *deb* is equal to *gfk* the total deviation is the minimum, and this is called the angle of minimum deviation for the prism.

When a beam of radiant energy containing more than one wave-length is sent through a prism, each wave length

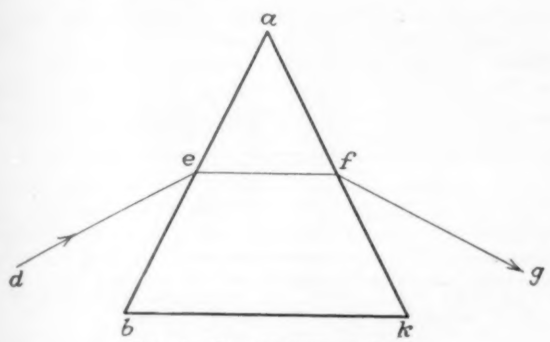


FIG. 2—REFRACTION IN PRISM
The Prism *bak* Is of Transparent Substance. It Changes the Direction of the Waves at *e* and *f*. The Deviation Is the Change in Direction Produced by the Prism, That Is, the Angle Between the Lines *de* and *gf* at Their Intersection When Produced

suffers a definite refraction which is different for each ray. The long wave-length is deviated the least. Also, each individual wave-length undergoes dispersion, but again the longer waves are spread the least. Thus, in Fig. 3, *d e* represents an incident ray of white light. The refraction at the point *e* will be different for each wave-length or color in the light. All the rays are refracted at the second phase and their paths become still more divergent for the different component colors as shown in the illustration.

Suitable prism-materials for investigation in the infra-red region are quartz, rock salt, sylvin, and fluorspar.

A spectrum is the representation of a spreading out of a beam of light or radiation into its components. A spectrum of a white light is a rainbow; that is, a white light is composed of many colors, namely, violet, indigo, blue, green, yellow, orange, and red. Violet has the shortest wave-length and red has the longest. All these colors are in the visible region of the spectrum. The ultra-violet has wave-lengths just shorter than the visible violet. The eye cannot see the ultra-violet ray, but a sensitive photographic plate will register it when exposed to its rays.

Infra-red rays are electromagnetic, invisible rays emitted from a body oscillating with a definite frequency. They have a greater wave-length than the red waves at the lower end of the visible spectrum as is brought out in Fig. 4. Infra-red rays are similar in character and general properties to rays of ordinary visible light. The sensations of warmth and vision are the effects of the same agent, an ethereal disturbance. They travel at the same velocity and are subjected to the same laws of reflection, refraction, and absorption to which visible light rays are subjected. The usefulness of a source is a function of the restriction of its application to that region of the spectrum which lies in its maximum intensity. The maximum amount of heat energy of the usual sources, such as hot bodies, is found in the upper infra-red region of the spectrum. The lower end is very weak in radiation and is, therefore, more difficult to investigate.

[4] See *Industrial and Engineering Chemistry*, December, 1925, pp. 1219 and 1226; and May, 1926, p. 528.

SCIENTIFIC STUDY OF DETONATION

A scientific study of the detonation of fuels was made by Clark and Thee at the Massachusetts Institute of Technology. Some of the results have been published[4]. Their method of investigation was to use a photographic spectroscope, which is an instrument for forming and ex-

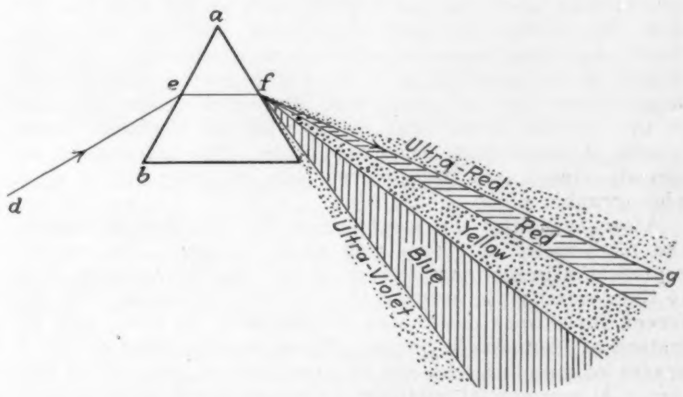


FIG. 3—DISPERSION AND SPECTRA
Deviation Depends Upon the Wave-Number of the Incident Waves, the Angle of Incidence, the Material of the Prism, and the Angle of the Prism. Waves of Greater Wave-Number, That Is, of Less Wave-Length, Are Deviated More Than Those of a Smaller Wave-Number. Thus Blue Waves Will Be Deviated More Than the Green and Red. The Difference in the Angles of Deviation Is Called Their Dispersion. When Waves from Any Source are thus Resolved into their Components, the Resulting Single Waves are Said To Form the Spectrum of the Source. If the Source is One of Ordinary White-Light, and If the Prism is One of Ordinary Glass, Its Spectrum, as Shown on the Screen, Will Be a Series of Waves which Produce in Our Eyes the Sensations of Blue, Green, Yellow and Red, as Well as All the Intermediate Shades

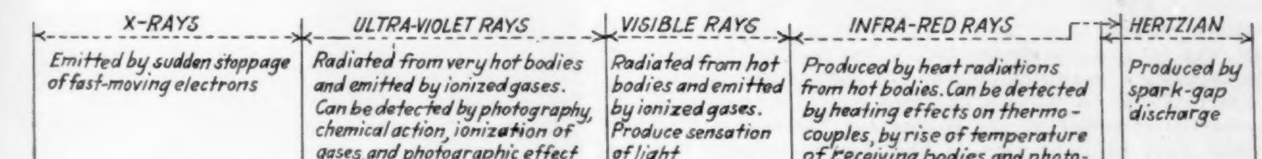


FIG. 4—RELATION OF VARIOUS REGIONS OF A SPECTRUM
In the Spectrum of a White-Hot Solid Such as Is Shown in Fig. 3, There Are Other Waves than Those Which Appeal to Our Sense of Vision; Some, Called the Ultra-Red Waves, Are Longer than the Visible Waves and May Be Detected by Their Heating Effect; Others, Known as the Ultra-Violet, Are Shorter and May Be Detected by Their Action on Certain Chemicals Such as a Photographic Plate. Beyond the Ultra-Violet and Still Shorter Are the X-Rays or Waves, While Beyond, That Is, Longer than the Infra or Ultra-Red Waves Lie the Hertzian Waves

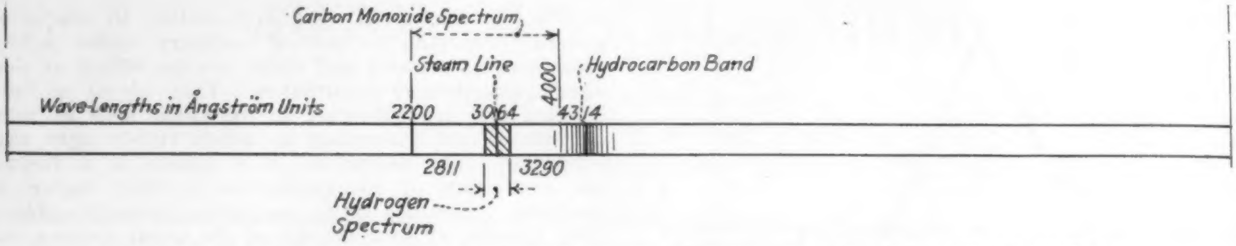


FIG. 5—RELATION OF THE SPECTRA OF THE ELEMENTS CONTAINED IN A CHARACTERISTIC MOTOR-FUEL
By Comparison with Fig. 4 It Will Be Noted That Part of the Spectrum Is in the Visible Region with a Wave-Length of from 5769 to about 4000 Ångström Units, and Part in the Invisible Ultra-Violet Region with the Minimum Wave-Length of about 2000 Ångström Units, Which Can Be Observed Only by Recording on a Photographic Plate

amining a spectrum of luminous bodies so as to determine their composition. In the case of this experiment, the spectrum is a band of light showing colors, or lines and bands, seen when a beam of light from any source, as an ignited vapor, passes through a lens and a prism. Fig. 1 is a diagram of the optical system of the spectroscope. Spectrograms may cover various regions such as the red, the yellow, the visible, the near ultra-violet, and the far ultra-violet, depending upon the wave-length of the light. In Fig. 5 part of the spectrum is in the visible region with a wave-length from 5769 to about 4000 Ångström units[3] and part in the invisible ultra-violet region with the minimum wave-length of about 2000 Ångström units. The ultra-violet, as already stated, can be observed only by recording it on a photographic plate.

After adjusting the spectroscope for the desired region, the ultra-violet spectrum was photographed. The results represent a preliminary survey of this field of research. Due to the necessity for keeping the results confidential, the different fuels were designated as Gasolines *A*, *B*, *C*, and *D*, instead of using trade names. These samples were ordinary grades of gasoline and can be purchased at any filling station. A commercial addition agent supposed to be potent in preventing detonation is represented by *E*. This supposed "dope" did not prove to be of any value in this experiment. It will be observed that the mercury-arc spectrum was repeated frequently. This was done to identify and locate the proper position of the spectrum of different kinds of fuel and calibrate each spectrum in wave-lengths by comparison with the lines of the mercury arc which have been identified by other scientists. The results are assembled in Fig. 6 which illustrates how the spectroscope gives us news of the various kinds of fuel used for internal-combustion engines. The method used for detecting the best fuel is described in the latter part of this paper. When the mixture was ignited the flame radiations passing through the quartz window were analyzed by the ultra-violet quartz-prism spectograph. A window of fused quartz was used in the combustion-chamber of the engine for the reason that ultra-violet rays or light rays of the invisible region will pass through this material and not through ordinary glass. The light-bands shown in the photographed spectrum represent the range of ultra-violet light and visible rays in flames, and are reproduced with the spectrum of a mercury arc as a standard for comparison in value.

From a scientific viewpoint this preliminary study has several very important results. To the layman, however, the most interesting is that it furnishes a practical analysis of the antiknock qualities of various kinds of fuel. The photographs show emission lines and absorption bands. Emission lines represent energy given out and the light-absorption bands represent energy imparted to the molecular structure of the substance to produce the chemical reaction or the combustion. The fuels showing the shortest light-bands in the photographs of spectra Nos. 7, 8, 9 and 11 shown in Fig 6 were found to be the most satisfactory; that is, free from knock. Nos. 7, 8, 9, and 11 are a spectra of a fuel that can be purchased very reasonably at filling stations selling gasoline which has been treated with tetraethyl lead. The fuel used in this test-run was treated with 0.1 per cent by volume of tetraethyl lead and an equal amount of ethyl bromide. No. 11 is a spectra of benzene.

To clarify the above, or to describe better the results obtained by this particular experiment, spectra Nos. 7, 8 and 9 are all of the same fuel used in the engine operated at different speeds and loads and obviously different openings of the throttle. The different lengths of time of exposure of the various runs were due to the variations in the intensity of the light, that is, while operating the engine at one-eighth throttle-opening, the intensity of the light or the flame in the combustion-chamber of the engine was so small that it

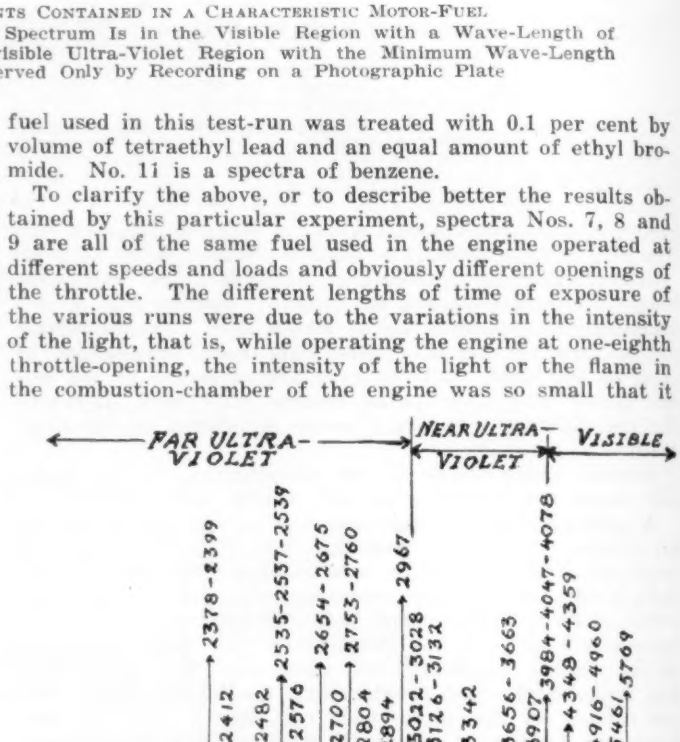


FIG. 6—ULTRA-VIOLET SPECTROGRAM OF MOTOR-FUEL FLAMES
The Ultra-Violet Prism Spectrogram of the Flames of Various Fuels Used in the Actual Operation of an Internal-Combustion Engine Referred to the Standard Spectra of a Mercury Arc in Vacuo. Data on the Different Spectra Are Presented Below

No.	Fuel	Time of Exposure, Min.	Position of Throttle	Speed, R.P.M.	Load, Watts
1	Mercury Arc	0.08			
2	Gasoline *A*	120	¾	1,300	498
3	Gasoline *A*	90	¾	1,300	498
4	Gasoline *B*	120	¾	1,280	528
5	Gasoline *C*	120	¾	1,280	528
6	Mercury Arc	0.06			
7	Gasoline *A* Plus Lead Tetraethyl	180	⅛	920	210
8	Gasoline *A* Plus Lead Tetraethyl	60	¾	1,500	1129
9	Gasoline *A* Plus Lead Tetraethyl	75	½	1,400	393
10	Gasoline *D*	60	¾	1,220	605
11	Benzene	75	¾	1,300	562
12	Gasoline *D* Plus Detonation Suppresser *E*	180	¾	1,240	627

[3] One Ångström Unit $=10^{-8}$ cm. $=0.00000001$ cm. (1 cm. $=0.3937$ in.)

was necessary to make a long exposure. On the other hand, the intensity of the flame at a three-fourths-open throttle was so great that a shorter time of exposure was sufficient.

Attention is invited to spectrum No. 8, where we have a well-defined light-band between 3907 and 5769 Ångström units, with a well-defined line of demarcation between the visible and invisible bands, indicating that in this sample of fuel there were little or no ultra-violet rays; and, further, in this sample there was no detonation, as compared to spectrum No. 3, which was common commercial gasoline and was run with a three-fourths-open throttle, identically the same as was sample No. 8, obtaining a speed of only 1300 r.p.m. with a load of 498 watts. The time of exposure of spectrum No. 3 was 90 min. The light-band in spectrum No. 3 is well defined throughout both the visible and the invisible or ultra-violet region, showing that radiations are emitted which affect the chemical composition of the fuel. This sample detonated very readily when the engine operated under load and ignition occurred under normal running-conditions.

Fundamental Principles of Detonation

To get down to fundamental principles and explain what causes knock or a detonation is very difficult. However, an attempt will be made, using the radiation theory.

As soon as the fuel is ignited and starts to burn around the electrodes of the spark-plug, a portion of the mass of mixture which is unburned is activated by radiations sent ahead by the flame as illustrated in Fig. 7. All radiation is produced by changing the motion of an electron. Electrons are evidently composed of ether, because they are electric charges and nothing else. We know that an electron has mass which is represented by its energy. We also know that a moving electron is more massive than one at rest, and that, as its speed increases, its mass and energy slowly increase.

It will be recalled that radiant heat can pass through a body without heating it. A wave of radiant heat can pass through part of the mixture without raising its temperature. The more dense the mixture vapors are, the less easily the radiant heat will pass through and the more of it will be absorbed by them. This absorption of the radiations tends to decompose the hydrocarbons constituting the vapor. This decomposition produces carbon, lighter hydrocarbons, and possibly hydrogen. The last two immediately ignite and burn with subnormal rapidity. The knock may be produced by a pressure wave resulting from this sudden combustion.

It will be observed that some of the fuels emit near ultra-violet and far ultra-violet radiation while the spectra of Gasoline *A* with ethyl fluid and benzene added are almost entirely in the visible region. If the fuel detonates easily, the burning fuel will emit ultra-violet radiation and X-rays. The lines in the spectrum correspond to some chemical reaction or physical change in the elements forming the combustible compound. When radiation is emitted, emission lines appear in the spectrum. When radiation is absorbed, absorption bands appear in the spectrum. Therefore, it appears that the spectrum with the smallest number of emission lines and the narrowest absorption band is the fuel which is free from knock under the ordinary conditions.

It will be observed that a spectrum of benzene or of fuel containing tetraethyl lead is very short. These fuels are free from the characteristic knock known as detonation because they do not emit ultra-violet radiation, which activates the unburned fuel, or decompose the hydrocarbons composing the vapor. Particular attention is invited to the spectra of benzene and Gasoline *A* with tetraethyl lead added. It will be observed that there are practically no emission lines or absorption lines or absorption bands in the ultra-violet region, that is, the light bands are not continuous as in spectra of a knocking fuel.

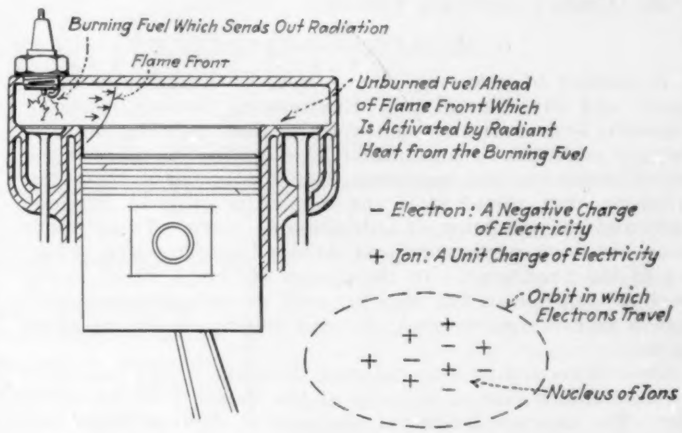


FIG. 7—DIAGRAM ILLUSTRATING THE RADIATION THEORY OF DETONATION.

With Ignition of the Fuel around the Electrodes of the Spark-Plug, a Portion of the Mass of Unburned Mixture Is Activated by Radiations Sent Ahead of the Flame as Illustrated at the Left. All Radiation Is Produced by Changing the Motion of an Electron. The Absorption of Radiant Heat Tends To Decompose the Hydrocarbons Constituting the Vapor, Thus Producing Carbon, Lighter Hydrocarbons, and Possibly Hydrogen. The Last Two Immediately Ignite and Burn with Abnormal Rapidity. The Knock May Be Produced by a Pressure-Wave Resulting from This Sudden Combustion

Knocking or detonation has been reduced at present by chemically treating the fuel. I believe that better results can be obtained by redesigning the engine. The factors which should be considered chiefly and can be applied to actual engineering design are the diameter of the cylinder, the stroke of the pistons, the turbulence, the method of ignition, the temperature of ignition, and the degree of compression.

The application of the solutions to the factors affecting the knocking or detonation of motor fuels will make possible the design of engines to operate under greater compression-pressure, thus affording much more power and many more miles per gallon of fuel. From the standpoint of available supply, petroleum oils must be used as the principal source of motor fuels for many years to come. From a commercial viewpoint, therefore, the problem is to find a means of controlling the detonation of paraffin hydrocarbon, a tendency which becomes more pronounced as their molecular size increases or their volatility decreases, or, in other words, as the cheaper fuels or heavy ends of the crude petroleum are used. By making a scientific research on each of the factors affecting detonation, an engine could be designed which would permit the use of cheaper fuels, thereby making the expensive operation of cracking fuels unnecessary and increasing the mileage of a gallon of fuel fourfold at least.

NOTES ON HEADLIGHT RESEARCH

How Automotive Lighting Is Adapted to and Dependent on Driving Conditions

During the last month two items of interest in the field of headlighting have come to the attention of the Research Department; one, a comprehensive outline of the history and the present status of the Society's headlight research; the other, a report of some new headlight research being carried on by an independent investigator. The first was prepared by H. M. Crane[6], chairman of the Headlight Subcommittee of the Research Committee. It was drawn up at the request of the Committee on Production and Application of Light of the American Institute of Electrical Engineers for use in its annual report. The second gives an account of tests made at the Edison Lamp Works of the General Electric Co., to determine the effects of wet roads on automotive headlights; it is a short, preliminary summary and gives an emphatic indication of the interest that will attach to the complete report, to be presented in a paper by R. E. Carlson[7] and W. S. Hadaway[8] at the Summer Meeting.

[6] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[7] M.S.A.E.—In charge of automotive lighting, Edison Lamp Works of the General Electric Co., Harrison, N. J.

[8] Engineer, automotive lighting section, Edison Lamp Works of the General Electric Co., Harrison, N. J.

Mr. Crane's statement follows:

H. M. Crane's Statement

A number of years ago the Society of Automotive Engineers and the Illuminating Engineering Society, working together, endeavored to improve the then existing unsatisfactory condition of automobile headlighting by adopting a set of minimum and maximum limits covering a light distribution that would yield the maximum of good driving-light and the minimum of objectionable glare. These limits were based on permanent and fixed adjustment and pointing of the headlights. In the nature of things, these limits were a compromise but were so well worked out as to produce a marked improvement in road driving-conditions after dark.

Since these limits were adopted, however, there has been a very marked change in many of the elements of the problem. The average height of the eyes of drivers above the road surface is considerably less than it was 5 years ago. This is due to the constant lowering of cars because of public preference for low appearance. Vehicle springs are now being made much softer than they used to be. Cars therefore pitch through greater angles due to road inequalities. Furthermore, because the passenger load comes very largely on the rear springs, there is a big change in car angle under varying conditions of load.

Having these changed conditions in mind, at a joint meeting of representatives of the Society of Automotive Engineers and of the Illuminating Engineering Society, it was voted unanimously that it would be desirable to work out a new set of limitations on the basis that a different type of light distribution should be provided for use in passing cars than that used in ordinary driving. The driver is then expected to change from one type of distribution to the other as conditions demand. Experience has shown that most drivers can be trusted to do this if they are provided with a reasonably good passing light. The old system of reducing the candlepower by dimming is condemned by everyone and it is hoped that it will become obsolete in the near future.

At the present time a Joint Committee, composed of members of the two Societies, is conducting research to determine the proper limits to adopt to govern the new types of light distribution. Without waiting for the final results of this Committee's work, many motor-car companies are adopting systems in which the regular driving-beam is lowered through an angle of 2 or 3 deg. in passing another car. A number of simple and economical ways are now available for accomplishing this result and the public approval of the change has been very marked.

How Wet Roads Affect Headlights

In their preliminary account of the investigation being carried out at the Edison Lamp Works of the General Electric Co., R. E. Carlson and W. S. Hadaway point out that tests have been made both in the laboratory and on the road to determine the effect of wet road-surfaces on the performance of headlighting equipment. Standard systems of both the fixed-beam and the depressible-beam type have been used, as well as special systems giving non-symmetrical light distribution.

The laboratory results so far obtained include a photographic record of the various beams at two distances, namely 57 and 85 ft., under both wet and dry surface conditions. Photometric readings have also been made indicating what happens when either the upper or the lower, or a special non-symmetrical beam, is used on a wet surface. In the laboratory work the measurements were made using only one surface, a concrete floor—but various types of beam were included.

The studies made on the road were intended to indicate the ability to see clearly, using different distributions of light and meeting different distributions of light. The procedure followed was to set up two test-cards, properly equipped, and to use a standard British Engineering Standards Association test-disc as a target. The distance at which this test-target could be clearly seen was taken as an indication of the ability to see under the various test-conditions.

Comparisons were made using the same light distribution on both cars for both dry and wet road-conditions.

The effect of road illumination near an oncoming car was also studied in an endeavor to determine the possibilities of silhouette vision.

A symmetrical system was studied which, through the use of two-filament lamps, could be made non-symmetrical by shifting the upper, high-intensity portion of the beam for driving.

The work is still in progress and the final results, to be presented at the Society meeting at French Lick Springs this month, promise to be such as to draw the attention of everyone desiring to gain information on the effectiveness of automobile headlights.

FERROUS METALLURGY REVIEWED

Treatise Is Designed To Give Mechanical Engineers Fundamental Information

Metallurgical subjects form the basis for many of the questions put to the Research Department by members of the Society and other inquirers. The properties of metals, their suitability for divers purposes, their treatment and working and a host of similar topics are touched on in the letters that come in daily. This well-demonstrated interest prompts a conspicuous reference to a book that is designed to satisfy it, that does for its field what the work of Dr. Clark and Lieutenant Thee does for the field of X-ray spectroscopy. This book is Principles of Metallurgy of Ferrous Metals, by Leon Cammen, which is published by and can be obtained through the office of the American Society of Mechanical Engineers, in New York City, at the price of $2.

The mechanical engineer's lack of knowledge of metallurgy augurs no lack of academic training or post-graduate intellectual activity. Alexander Graham Christie, in a foreword to the present treatise, aptly points out the difference between the context of the science today and the university courses on it of 10 or more years ago. Books would naturally be the source of instruction for the practising engineer, but these, as is to be expected for a science whose methods have been so recently and so radically revised, have been, for the most part, too technical and too detailed, and, in some instances, too controversial in subject matter, to serve his purpose. His need has been a treatise sufficiently simple in expression to be readily understood without recourse to a scientific dictionary, sufficiently brief to be sandwiched in with other tasks of a crowded day, and yet comprehensive, accurate, authentic, non-controversial, and uptodate.

In the space of 150 pp. Leon Cammen succinctly sets before his readers the fundamentals and terminology of the new metallurgy. Presenting only essential material, and this in the simplest of terms, he tells in six chapters what the engineer wants to know about the properties of ferrous metals, their structure, and methods of testing, treating and utilizing them. A metallurgist of established reputation, his work bears the stamp of authenticity. Controversial matter is clearly labeled as such.

The necessity for alertness in keeping pace with current metallurgical developments and the extent to which this book meets the need is shown by its history. The material was first published as a series of articles in *Mechanical Engineering* in 1925. When it was assembled in book form for the first time, in February, 1926, about 4 months after the appearance of the last article, extensive revisions were called for, due to changes in metallurgical practice, and these were made. The present second edition incorporates a number of still more recent developments.

For the reader who wishes to carry his study further, numerous references to more detailed treatises are included. In short, the book fulfills the promise of its subtitle, A Manual for Mechanical Engineers, and will prove a worthwhile addition to any engineer's library.

PRODUCTION ENGINEERING

The production engineer is a man of science who figures cause and effect, utilizing a scientifically selected means to accomplish predetermined results. His position today requires a keen, receptive and analytical mind, and the reactions with which he works in terms of rate, time, volume, and cost form a more exact science due to his own patience and labor.

NOW that the frenziedness of quantity production has, for the more progressive plants, passed into history and the production engineer has discovered what it is all about, he emerges from the chaos and confusion with several definitely established ideas which he has proved to his own satisfaction. The fact that these ideas have been proved establishes them as principles of the science of production and dignifies the erstwhile production man as an engineer of that science.

Not that quantity production has passed, only the frenzied features of it, for the principles of production science have specified methods with known results and have smoothed the path to greater volume. Even the principles are not new but the last few years have constituted crucial tests and their success or failure has been measured in quality and cost. Only a few years ago one of the progressive manufacturers of better cars stated, in effect, that there is nothing inherent in quantity production that makes quality impossible to attain, and since then several builders have proved not only that quality could be maintained but also that costs could be reduced. All of which reverts directly to the ability and progress of the production engineer and the progress of his science.

One of the first ideas in quantity production was that of multiplying the single unit of equipment to obtain multiple production. If one press, or one lathe, or one unit of equipment would produce a certain quantity, then two or three would produce twice or three times as much. But herein was a multiplication of the waste and loss that existed in the original unit. This multiplied, also, in direct ratio, most of those functions which are essential to production yet not directly productive and, if it did not increase the labor factor in the same proportion of a man to a machine, there was a disgruntled attitude and results were obtained if, as and when the operators were willing. Certainly it multiplied, almost in progressive ratio, the woes of the production engineer. But it was the easiest way to maintain balanced volume throughout the whole line.

Man and Machine Studies Cut Cost

To eliminate some of this undesirable repetition and to increase production without a proportional increase of investment and cost, certain definite steps toward economy came into practice: double fixtures on a single-head machine to keep it producing, combined tool set-ups, combined units of equipment under one operator covered with a hop, skip and jump that produced a piece, perhaps, every few minutes, and other makeshift combinations. All of these represented some gain and production flowed on accelerated.

A little serious thought and study, however, developed even greater improvements. First there was the efficiency of labor, and previous principles showed that a short cycle of repetitive operation per man was faster and more economical than a longer cycle. Then, there was the machinery factor, and what could be done by machine was generally cheaper and better done than if done by hand.

The design of the piece and the nature of the operations required determined natural grouping. There were single-operation jobs or simple combinations that formed natural units for production, and there were other jobs that required a series of operations of the same or similar character, a manufacturing process that comprised a natural unit for production.

In the recognition of these classes of work, and the determination of them, the production engineer evolved new principles. He readily admitted adherence to the science of metal cutting, or the "art," as Mr. Taylor preferred to call it, which specifies definite speeds and feeds, shapes of tools, and the like. He had previously applied to advantage the division of labor into short cycles and had employed machines into which the skill and intelligence of the workman had been transferred. But now he complied with all the known rules and evolved others in combining operations in their natural grouping for even greater economy.

Repetitive Single-Operations Speeded Up

For the short-cycle job and repetitive single-operation, he used identical units, combined in batteries or in one machine, synchronized and under one operator. Automatic operation was, to a certain extent, a measurable recompense to labor for the added burden of multiple units. The time of the cycle set by the maximum speed of performance for the job determined the number of units one operator could attend with the minor functions required of him. There was marked here an economy in production cost due to the automatic feature and to the opportunity thus presented to spread labor cost thinner on each piece produced.

A further study proved that investment and the carrying charges could be made to contribute a portion of economy and that, by further refinement of the process, all items of production cost could be so handled as to gain respective amounts of saving. For this reason, processes of manufacture were combined with progressive transportation of the parts through the plant. Machining functions were combined insofar as the mechanical requirements of each operation permitted and, where single production-units were multiplied in one machine, they were provided with drive or feed or speed mechanisms in common to reduce investment charges, or space or power consumption, or essential handling. The desirable equipment or method, therefore, required for short-cycle work was a multiplication of simple identical units with mechanical functions in common and centralized so far as possible.

New Principles Involved for Multiple Operations

For the second group of parts, those requiring a series of operations, virtually constituting a manufacturing process, the methods determined were somewhat different. The idea of dividing the work was still followed. The mechanical requirements for maximum production in each single operation were determined and followed so that the final detailed analysis of any piece, consisting of from 5 to 50 or more primary single-operations, was a tabulation with the method and rate of performance for each operation clearly specified including the total time required. Then it became a matter of combining by wise selection to avoid incompatibility in the nature of the work. It was further necessary to select carefully with exact study of the mechanical requirements of each operation to avoid compromise in rate of performance

and thus build, from the tabulated list of primary operations on a given piece, a carefully studied process by which all of this work might be performed.

This method of planning production portrays a distinctly new principle in production science. This involves, first, breaking down the job to be performed into primary functions entirely disintegrated into work units, then rebuilding again through a process capable of performance on the equipment available and complying with all specifications and governing codes, integrating the work units to a manufacturing process.

In combining the operations and assigning them to various production units, it was especially necessary to maintain balance throughout the process on each unit. Where production units were combined under centralized control and necessarily synchronized, exact balance was even more essential.

Automatic multiple-unit machines required independent factors of rate of speed and rate, amount and direction of feed in each unit—universal adaptability to all operations within its class. In the process of building the manufacturing method, primary operations were split or combined to balance the load required of each unit and the time required for the performance of the work.

Production Capacity Planned for Expansion

But, having labored long and having evolved a new principle of production from observations in his own field, the production engineer extended his observations to include the complete manufacturing process from raw material to finished product and, knowing now what to observe, he found again on a broader scale that new principle of integrated manufacture. A casual glance at other industries, such as process industries in cement and flour and paper, or in other classes of manufacture whatever the material or product, showed that in each case this new principle was an essential factor.

He further noted that any deviation from this principle of integrated manufacture inevitably resulted in loss of production efficiency and economy. But wherein theoretical perfection formed a desirable objective, the practical application of the principle would always remain relative. For new plants or for the expansion of productive capacity, the idea could be followed quite completely, but in replacement of older equipment the economy of integrated manufacture must show a sufficient margin over the old method to be economically justified on the investment basis.

In planning production then, he classified methods by their scope in volume wherein each method rendered greatest economy. For the smaller quantities, single units and double units were satisfactory, but, as quantities increased, the savings per unit of production were sufficient to pay for automatic features and multiple equipment. It was found, however, that, while too much equipment for the job brought on heavy carrying charges, it was yet good policy to plan for a margin of productive capacity on the expansion side; in this way taking advantage of the economy features of the more highly developed methods. And if his production schedule did not always require a full day, the savings from the volume that was available at any time were generally sufficient to more than offset the carrying expense of better equipment for a reasonably short idle period.

Production Engineer of Primary Importance

The production engineer is, therefore, a man of science who figures cause and effect, utilizing a scientifically selected means to accomplish predetermined results. His position today requires a keen, receptive and analytical mind, and the reactions with which he works in terms of rate, time, volume, and cost form a more exact science due to his own patience and labor.

The production engineer has arrived. He has established himself among manufacturing executives as a man of primary importance. He has worked out his practical problems and evolved the principles of his science, making practicable the theories and ideas that have been handed down to him from the first conception of production science, almost 200 years ago. The automotive production engineer has had the opportunity to accelerate the development of this science and the last 25 years has done more to increase the importance and bearing of this science than any previous period.

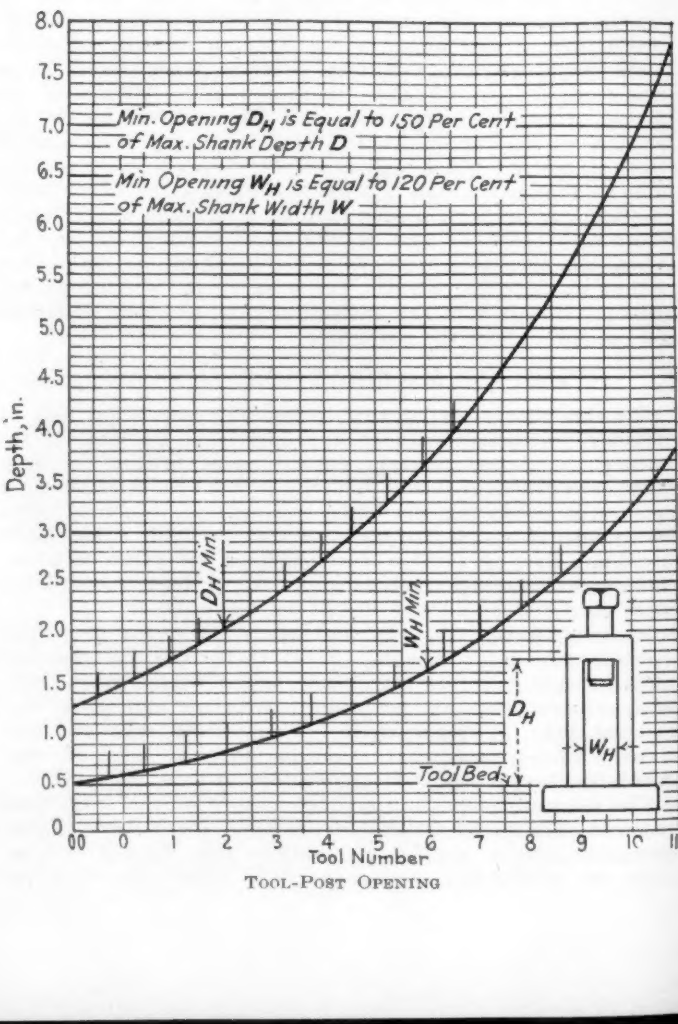
Now the production engineer has arrived at an era of economy. Mere volume is not sufficient to show profits. Competition has brought down the sales prices, and constructive profits from now on must be accumulated from the small savings in production centers of manufacturing. The production engineer faces a new problem of selection and refinement of methods wherein lies the greatest possibility for substantial gain to his whole industry.

TOOL-HOLDERS AND TOOL-POST OPENINGS

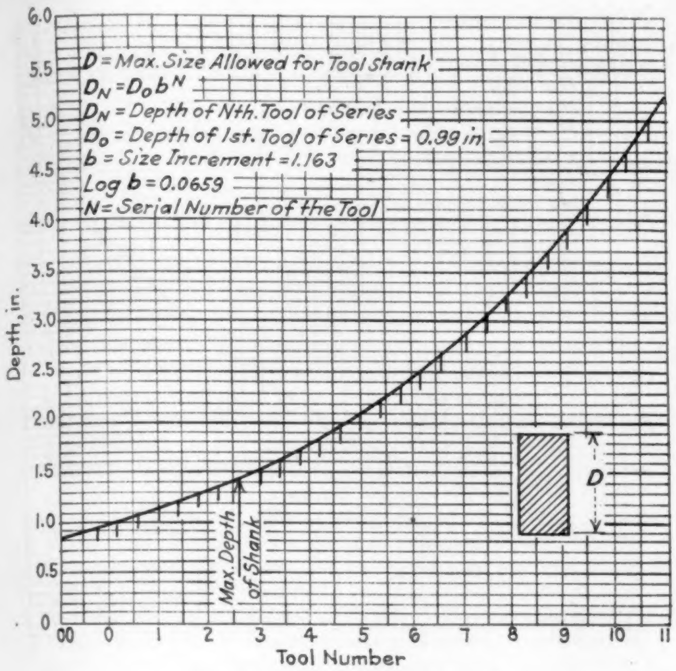
Proposed Standard Referred to Production Division of Standards Committee

In September, 1924, a conference held at New Haven, Conn., under the auspices of the Sectional Committee on Small Tools and Machine-Tool Elements, decided to undertake the standardization of tool-holders and tool-post openings. A subcommittee was eventually organized and held several meetings as the result of which the following report has been released for study and comment by the machine-tool manufacturing and using industries.

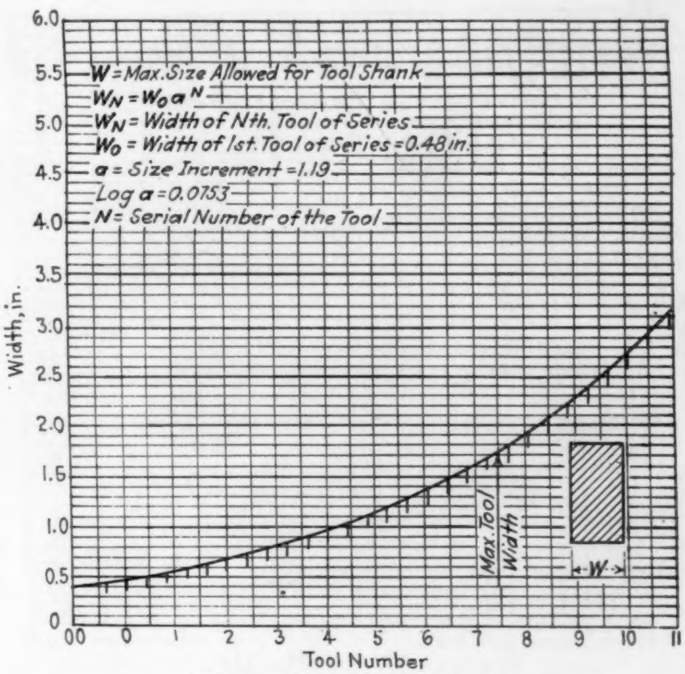
Copies of the report were sent to the members of the Production Division of the Society's Standards Committee for study and criticism because the report, when submitted to the Society as one of the sponsors for final approval, will be assigned to the Production Division for consideration and action in accordance with the Society's Standards Committee procedure. The Society has not designated representatives on the subcommittee, but is represented on the Sectional Committee, through which the report will pass, by W. G. Careins, A. H. Frauenthal, L. F. Maurer and E. N. Sawyer.



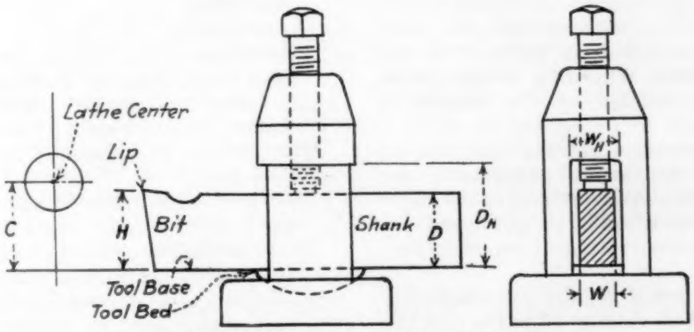
Tool-Post Opening



Depth of Tool-Shank Section

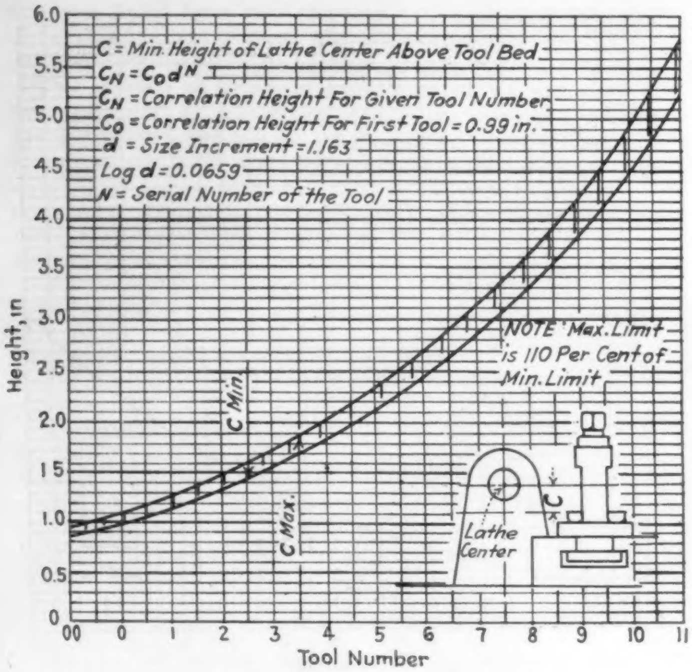


Width of Tool-Shank Section

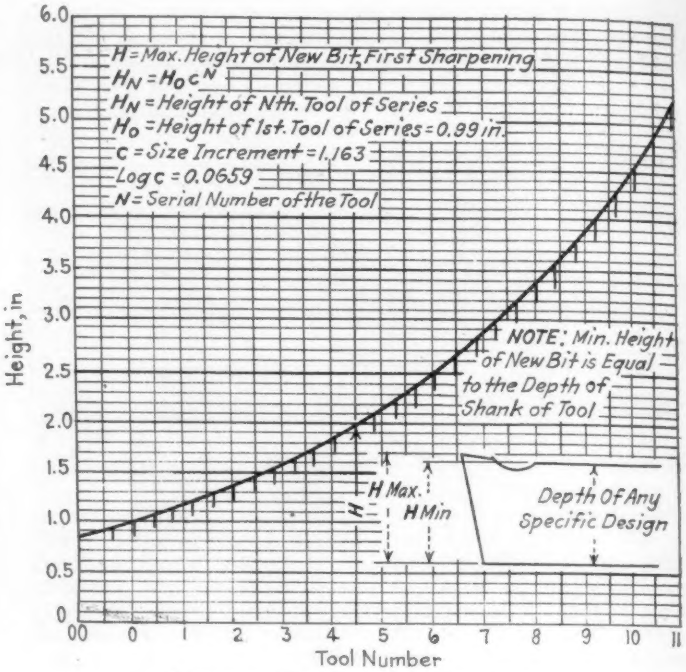


ARRANGEMENT OF TOOL POST AND TOOL

Serial No.	Shank Section			Tool-Post Opening			Height of Lathe Center C			Height of New Lip H	
	Maximum			Minimum							
	Depth D	Width W	Nominal D x W	Depth D_H	Width W_H	Nominal D_H x W_H	Minimum	Maximum	Nominal	Maximum	Minimum
00	0.85	0.40	⅜x ¾	1.27	0.49	1⅜x ½	0.85	0.93	⅞	0.85	
0	0.99	0.48	7/16x ⅞	1.48	0.57	1½x 9/16	0.99	1.09	1	0.99	
1	1.15	0.56	½x1	1.72	0.68	1¾x 11/16	1.15	1.26	1 3/16	1.15	
2	1.34	0.67	⅝x1¼	2.00	0.81	2 x13/16	1.34	1.47	1⅜	1.34	For Lathe Tools This Value Is Equal To The Shank Depth
3	1.56	0.80	¾x1½	2.34	0.96	2⅜x1	1.56	1.72	1 9/16	1.56	
4	1.81	0.95	⅞x1¾	2.71	1.14	2¾x1⅛	1.81	1.99	1 13/16	1.81	
5	2.11	1.13	1 x2	3.16	1.35	3⅛x1⅜	2.11	2.32	2⅛	2.11	
6	2.43	1.34	1¼x2¼	3.65	1.61	3 11/16x1⅝	2.43	2.67	2 7/16	2.43	
7	2.86	1.60	1½x2¾	4.29	1.91	4¼x1⅞	2.86	3.15	2⅞	2.86	
8	3.34	1.90	1¾x3	5.00	2.27	5 x2¼	3.34	3.67	3⅜	3.34	
9	3.87	2.26	2 x3½	5.80	2.70	5¾x2¾	3.87	4.25	3⅞	3.87	
10	4.50	2.69	2½x4¼	6.75	3.21	6¾x3¼	4.50	4.96	4½	4.50	
11	5.25	3.20	3 x5	7.87	3.84	7⅞x3⅞	5.25	5.77	5¼	5.25	



HEIGHT OF LATHE CENTER ABOVE TOOL BED



HEIGHT OF TOOL LIP ABOVE TOOL BASE

The text of the report is published in this issue of THE JOURNAL to bring it before the members of the Society, particularly those who are interested in machine-tools, for their study and comments before it is acted on further by the Subcommittee. All communications regarding it should be addressed to the Standards Department of the Society in New York City.

In formulating a proposed standard it was the aim of the Subcommittee to correlate so far as practicable the existing standards of American tool manufacturers. As these are nearly identical and are scientifically proportioned, no consideration has been given to correlating them with foreign practice.

It was realized that the tools would require standardizing to make the standards for posts and clamps effective and the Subcommittee accordingly exceeded its original instructions and submits the tool series as a portion of the report. To restrict design as little as possible by the proposed standard, no definite sizes are recommended, but the maximum metal-value for the tool shank, the minimum metal-value for the post opening and a tolerance on the height of lathe center are submitted.

The maximum metal value of the tool shank exceeds in practically every case the shank size of tools which are now in use, so that existing stock may be used in future machine-tools that are influenced by the standard.

The series presented herewith is in geometrical ratio so that it may be expanded indefinitely to meet future needs.

PROGRESS REPORT OF SUBCOMMITTEE NO. 2

TERMINOLOGY

Tool.—A non-adjustable cutting-device consisting of a bit and shank of the same forging, or a bit attached to the shank by welding. The device is restricted to the three general types adapted to lathes, planers and shapers.

Tool-Holder.—An adjustable cutting-device consisting of a replaceable bit clamped to the shank.

Bit.—The adjustable cutting-portion of the tool-holder, or the cutting portion of a solid tool.

Tool Base.—The plane of the shank which engages the tool bed.

Tool Bed.—The plane of the machine-tool against which the tool is clamped; the rocker of a lathe post.

Tool Post.—The slotted clevis-shaped clamp as regularly used on lathes and shapers.

Tool Clamp.—Any tool-holding device such as the open-side clamp used on square turret-attachments to the lathe and the plate and cap-screw clamp used on planers.

Width.—The transverse thickness of the tool shank or the slot width of the tool post.

Depth.—The transverse depth of the tool shank or the slot height above the bed of the tool.

Height.—The nominal distance from the tool base to the cutting-lip of the bit.

OF INTEREST TO PRODUCTION ENGINEERS

Production engineers will find much of interest to them in a book recently published by the American Society of Mechanical Engineers, entitled Principles of Metallurgy of Ferrous Metals, by Leon Cammen. This is a brief, practical treatise, designed to give to mechanical engineers the information concerning metals that they need in the exercise of their profession.

Tests of Pneumatic Means for Raising Airfoil Lift and Critical Angle

By E. N. Fales[1] and L. V. Kerber[2]

Illustrated with Photographs and Drawings

ABSTRACT

Discovery of a satisfactory method of increasing the maximum lift of an airplane wing that should have structural simplicity, high wing-loading, low landing-speed and reasonably low drag, was the object of experiments and wind-tunnel tests made by the engineering division of the War Department Air Service at McCook Field. Previous study of the "burbling" characteristics, or discontinuity of air-flow, of airfoils at McCook Field indicated that the attainment of high lift depends upon an extension of the burble angle, that the angle at which burbling occurs can be controlled, within a range of about 5 deg., by changes in velocity or in turbulence of the wind, and that if burbling can be deferred artificially still further than the 5-deg. range the lift will increase in the same proportion.

Studies abroad with rotating cylinders and the magnus effect confirmed the boundary-layer theory and principles enunciated by Dr. Prandtl in Göttingen and showed that discontinuity of air-flow, which usually occurs first at mid-span of the wing, need not be regarded as incurable. Some success was attained at McCook Field in regulating the boundary-layer effects by use of a jet of air made to flow tangent to the upper surface of an airfoil to blow away the turbulent skin-frictional layer of air and draw it downward from its burbled position into contact with the airfoil. These experiments are described and the results given.

Greater success in deferring the burble angle was attained recently in Göttingen by inducting the boundary-layer air into the wing through perforations in the airfoil by suction, thereby increasing the angle of maximum lift and the maximum lift itself threefold. Details of tests by both the jet aspiration and the boundary-layer induction method are given in the paper. The tests were made with a 6x18-in. wooden airfoil-model in a wind-tunnel provided with glass sides for observation. The surface of the airfoil was coated with a mixture of lampblack and kerosene in which the air currents created flow-lines that were photographed. In the induction tests the number and location of the induction perforations were varied and the angle of the airfoil was varied.

Results obtained show that with the aspirator jet the lift is increased throughout the range of angles tested, that the burble angle can be deferred 2 deg. by the jet and the maximum lift increased 35 per cent, and that the drag is also increased although in a smaller proportion. With the induction method it is concluded from the evidence of the photographs, that the burble angle can be raised 25 deg., or 10 deg. above normal, and that its benefits are noticeable for angles as high as 35 deg., or 20 deg. above normal. At the same time the drag is decreased. Power required for operation of the suction-pump is estimated at approximately 4 per cent of the power needed for flight.

Much wind-tunnel research has been directed toward the discovery of a satisfactory high-lift wing that would have the advantages, so greatly desired by airplane designers, of structural simplicity, high wing-loading, low landing-speed, and, if possible, reasonably low drag. Familiar examples of such developments are the thick airfoils of Junkers; the slotted airfoils of Handley-Page[3] and Lachmann[4]; the auxiliary-flap airfoils of Jacobs[5] and of Wragg and Crooke; the rotating windmill of Cierva[6], and rotating-cylinder applications, such as those developed by Gligorin[7], Wolff[8] and Frey[9].

At McCook Field, where more than usual attention has been given to study of the "burbling" characteristics of airfoils, the attainment of high lift has seemed to depend on an extension of the burble angle. This angle, which is sometimes called the critical angle, is the angle of maximum lift because, for any higher angle, the air-flow separates from the back of the airfoil, with resultant loss of efficiency. Tests have shown that, although coefficients applying to the burble have in the past generally been classed as erratic and unreliable, they nevertheless can be definitely measured, and their "unreliability" can be traced to the effect of velocity and turbulence[10]. These tests showed that, within a limited range of about 5 deg., the angle at which burbling occurs can be controlled either by changes in velocity or in turbulence of the wind. Within this limited range the increase of the burble angle was accompanied by an upward extension of the lift curve at a slope not greatly different from the general mean slope. It was easy to imagine that, if burbling could be deferred artificially still further than the 5-deg. range, the lift would rise in the same proportion.

It has further been a matter of common knowledge that the critical angle of airfoils arranged in multiplane is greater than for a single airfoil. It has also been known that decrease of aspect-ratio in an airfoil brings about a greatly increased critical angle and a correspondingly increased resultant force. The latter arises no doubt from the fact that the centripetal force on the air over the tips is greater, due to proximity of the tip vortex, than at mid-span, so that burbling usually occurs first at mid-span; thus, for low aspect-ratios, where the

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[2] Aeronautical engineer, materiel division, Air Corps, McCook Field, Dayton, Ohio.

[3] See British Advisory Committee for Aeronautics Reports and Memoranda No. 834; also National Advisory Committee for Aeronautics Technical Memorandum No. 369.

[4] See McCook Field Memorandum Reports Nos. 136 and 137; also National Advisory Committee for Aeronautics Technical Memorandum No. 298.

[5] See Massachusetts Institute of Technology Wind-Tunnel Files for Aug. 2, 1921, test of airfoil with split trailing-edge.

[6] See *Journal of the Royal Aeronautical Society*, January, 1926, p. 8.

[7] See McCook Field Wind-Tunnel Files, Test No. 216.

[8] See National Advisory Committee for Aeronautics Technical Memorandum Nos. 307 and 354.

[9] See National Advisory Committee for Aeronautics Technical Note No. 382.

[10] See McCook Field Serial Report No. 2080, for 1922; McCook Field Airplane Department Memorandum No. 821, for 1926; McCook Field Test No. 263-a; and National Advisory Committee for Aeronautics Report No. 83.

tip effect is relatively powerful, discontinuity of flow is deferred[11].

In connection with the problem of controlling discontinuity in air-flow, the rotating-cylinder development of 1924 has great significance. This device, although mechanically impracticable for aircraft, furnished empirical corroboration of Dr. Prandtl's boundary-layer theory[12] and showed clearly that discontinuity of flow, or "burbling," need no longer be regarded as an incurable evil in aerodynamics.

New interest in high-lift airfoil research was at once aroused thereby and numerous projects were started with the object of applying to airfoils the boundary-layer principles enunciated at Göttingen.

Air-Jets Regulate Boundary-Layer Effects

Some success was attained at McCook Field with the use of pneumatic rather than mechanical means of regulating the boundary-layer effects. A jet of air was made to flow tangent to the upper surface of an airfoil for the purpose of substituting a moving film of air for the moving periphery of the rotating cylinder and to blow away the turbulent skin-frictional layer, and to thus "aspirate" the main air-flow, drawing it downward from its burbled position into contact with the airfoil. These experiments are described in a report made at the time of the tests in 1925, excerpts from which are given later herein.

Still greater success in deferring the burble angle was reported recently by members of the staff at Göttingen[13]. The method used likewise involves a pneumatic means, but instead of blowing the boundary layer away by means of a jet of air, it is inducted through perforations into the wing itself, which is made hollow and connected to an exhaust-pump for the purpose. A three-fold increase both in the angle of maximum lift and in the maximum lift itself has been reported.

The Göttingen induction method, which has been verified by tests at McCook Field, seems to be more practicable than the jet method, as it does not require so wide a range of operating pressures and hence less power at the blower is needed. Details of tests on the two pneumatic methods of increasing lift by (*a*) jet aspiration and (*b*) boundary-layer induction are here set forth.

Lift Increase by "Aspirator" Jet

Wind-tunnel test No. 144 at McCook Field was a rough examination of the possibilities of developing improved airfoil-characteristics by the application of the theory that a jet of air, in the region of the airfoil where the viscosity effect is important, will alter the flow advantageously because, since the velocity of the air passing an airfoil is a maximum at the upper surface between the leading edge and the thickest portion of the airfoil, a jet introduced into this region, blowing approximately tangent to the upper surface, should have a relatively large effect upon the effective skin-friction, in the same way as does the surface of a rotating cylinder.

An aspirating tube capable of discharging a sheet of air rearwardly in this high-velocity portion was built. The position of this aspirating tube was expected to be altered to find the best position and to examine whether favorable or unfavorable results would be observed; but, as the first setting was sufficient to verify the aspiration principle, other settings were not tried at the time. The effect observed from a single aspirating tube was thought to be sufficient; but it is held in mind that should a trial of the principle indicate that further investigation is worthwhile, a plurality of jets could be used, and that they could be located at any desired portion of the airfoil on either the upper or the lower surface.

The foregoing theory was arrived at from joint consideration of (*a*) some tests made by one of the authors in 1917 in connection with the aspirating effect of gaseous jets such as are used in the Stanley steam-automobile burner, (*b*) the Magnus effect on a rotating cylinder, and (*c*) the boundary-layer theory of Prandtl. The aim was to develop a high-lift wing, with the hope that this high lift would not necessarily be accompanied by excessive drag. Should the theory be shown to be correct, the further aim was to lay out a system for providing suitable jets on full-scale aircraft. The practical application of the principle would be sought first by utilizing the exhaust-gas, suitably cooled, of the aircraft engine; but whether the volumes and pressures of this exhaust-gas would be sufficient to secure practical benefit would have to be determined by quantitative wind-tunnel tests of the requirements. The engineering problem would be to expand and cool the hot exhaust, perhaps mixing it with cold air on the principle of the Alberger steam condenser. The thermodynamic energy in the exhaust from a 400-hp. airplane-engine has a value roughly equal to the rated horsepower of the engine. In the case of the Moss supercharger, 60 b-hp. is actually recovered out of the exhaust energy of a 400-hp. Liberty-12 engine.

A second and less attractive means of utilizing the principle would be an auxiliary device on the aircraft, such as a blower, that could be thrown into action when needed, as, for example, in landing.

Should aspiration prove impracticable for the whole wing-surface, there would still be the possibility of partial aspiration, say at the control surfaces, which could be given high or low lift at the will of the pilot by

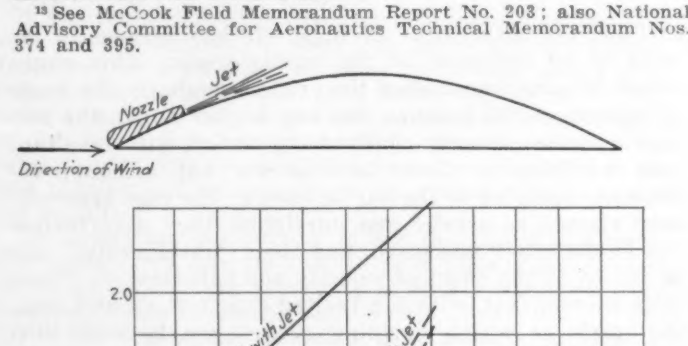

Fig. 1—Effect of Aspirator Jet on Lift and Drag of an Airfoil
In Tests at McCook Field with a 6 x 18-in. Airfoil Having a Camber of 0.15, the Jet Acted To Increase the Lift by Three-Fourths at a Zero Angle of Attack of the Airfoil and a 30-M.p.h. Current in the Wind-Tunnel, and by Two-Thirds at a 14-Deg. Angle of Attack

[11] See Resistance of the Air and Aviation, by Gustave Eiffel, pp. 40, 144 and 212; McCook Field Airplane Department Memorandum No. 748, Serial No. 2635; National Advisory Committee for Aeronautics Report No. 150; and British Advisory Committee for Aeronautics Reports and Memoranda No. 355.

[12] See National Advisory Committee for Aeronautics Technical Memorandum Nos. 209 and 310.

[13] See McCook Field Memorandum Report No. 203; also National Advisory Committee for Aeronautics Technical Memorandum Nos. 374 and 395.

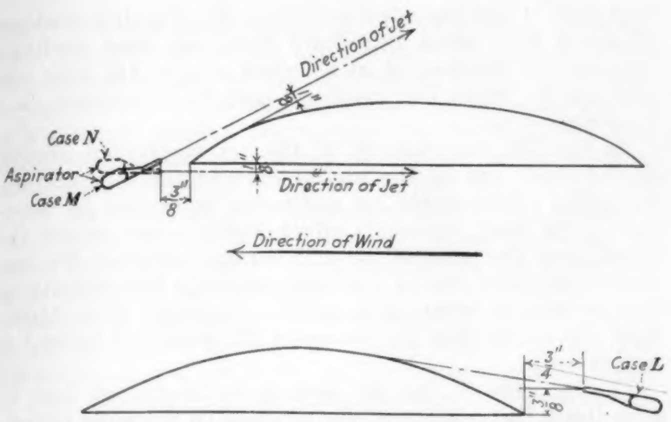

FIG. 2—ASPIRATOR DETACHED FROM AIRFOIL AND MOUNTED ON FLOOR OF WIND-TUNNEL

The Aspirator Nozzle Was Placed in Various Positions with Respect to the Airfoil, and the Action of the Jet in Altering the Aerodynamic Flow around the Airfoil Was Studied in Principle by This Means

manipulation of a suitable throttle, thus augmenting by pneumatic control the conventional mechanical-control system. This principle would also apply to dirigibles; a jet playing on portions of the envelope could, by altering the pressure distribution, give directional control independently of the usual rudders and other means.

After laying out a preliminary test of the principle a report[14] by G. Lachmann was received, in which it appeared that Lachmann had also conceived the idea of "blowing or sucking away the boundary layer"; but from a theoretical analysis of the problem he concluded that the size of jet necessary would be prohibitive.

ASPIRATOR-JET-PRINCIPLE TEST-METHOD

A wooden airfoil of 6-in. chord and 18-in. span, with circular arch of about 0.15 camber, was available. The position of the aspirating tube on the front upper part of this airfoil is shown on the diagram of the lift and drag-curves in Fig. 1. As will be seen, the position is such as to make a very poor airfoil-shape.

The airfoil was mounted in a vertical position on the National Physical Laboratory type of balance. The air pipe from the aspirating tube was allowed to project downward and to the rear of the spindle guard, where a ¼-in. inside-diameter air hose was connected to it as a means of communication with an air tank and air pump located outside the tunnel. The air hose was arranged for minimum change of position during the test and for minimum effect due to the pressure inside the tube acting to swing the balance; but for this rough preliminary test it was thought sufficient to take tare readings of the pressure effect on the lift and drag and by careful observation during the test to ignore the elasticity of the pressure hose. Therefore, before and after each test, lift and drag readings were taken with no wind in the tunnel but with full pressure in the tube and full velocity of the jet at the nozzle. These tare readings could then be subtracted from the lift and drag values taken with the wind in the tunnel at 30 m.p.h.

The air tank was too small for maintenance of a constant pressure at the jet, hence readings had to be taken very quickly, with corresponding inaccuracy. In consideration of all the sources of error in this set-up, the values given herewith cannot be taken as accurate, and they must be used only as a qualitative indication of favorable or unfavorable results.

RESULTS OF ASPIRATOR-JET-PRINCIPLE TEST

Referring to Fig. 1 it is seen that the jet acted to increase the lift three-quarters at an angle of zero deg. and two-thirds at 14 deg. The effective airfoil-shape was poor, due to the presence of the nozzle lying along the upper surface; therefore some supplementary tests were made in which the nozzle was separated from the airfoil and mounted rigidly to the floor of the tunnel, close to but not touching the airfoil, with the jet directed as in Fig. 2. The action of the jet in altering the aerodynamic flow around the airfoil was studied in principle by this means; and, although the presence of the nozzle gave a somewhat distorted flow at the outset, the change of forces with and without the jet could be determined accurately, because the tares due to jet reaction and hose elasticity were eliminated.

In Fig. 3 it is shown that, with the nozzle near the trailing edge and the jet directed forward, both lift and drag were affected unfavorably by the jet except for Case *N* (Fig. 2) with the airfoil at an angle of 10 deg. When the jet was directed from the front over the upper surface at zero deg., as in Case *L* (Fig. 2), the lift was increased 135 per cent, which was more than for the case of Fig. 1. Note that the zero-deg. angle of attack of this airfoil corresponds to an inefficient régime of flow under usual conditions[15]. The changes of lift and drag

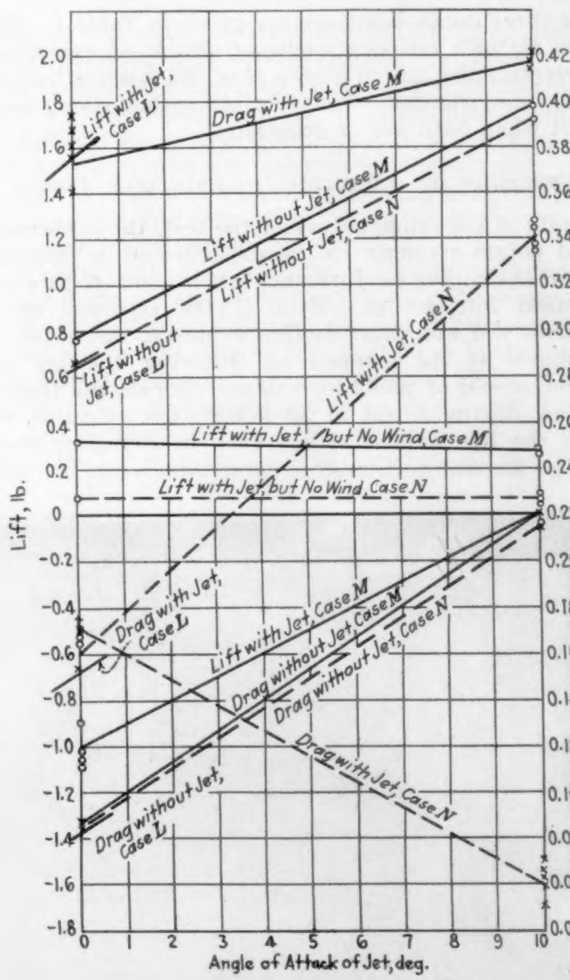

FIG. 3—EFFECT OF DETACHED-ASPIRATOR JET

With Nozzle near the Trailing Edge and Jet Directed Forward, as in Case *N* (Fig. 2) Both Lift and Drag Were Affected Unfavorably, the Lift Being Decreased and the Drag Increased. When the Jet Was Directed from the Front, or Leading Edge, as in Case *L* at the Bottom in Fig. 2, and over the Upper Surface at Zero Deg., the Lift Was Increased 135 Per Cent and Was Greater than the Lift at Zero Deg. in Fig. 1

[14] See National Advisory Committee for Aeronautics Technical Memorandum No. 298, p. 13.

[15] See McCook Field Serial Report No. 2635.

TABLE 1—EFFECT ON LIFT AND DRAG WITH ASPIRATOR JET IN VARIOUS POSITIONS

	Angle of Attack, deg.	Net Lift, lb.			Net Drag, lb.		
		Jet Only	Wind Only[16]	Wind and Jet[16]	Jet Only	Wind Only[16]	Wind and Jet[16]
Direction of Wind Case L	0		0.67	1.58[a]		0.083	0.153[b]
	0	0.30	0.76	1.04	0.01	0.087	0.375
Case M	10	0.28	1.78	0.00	0.02	0.221	0.419
	0	0.08	0.66	0.52	0.09	0.085	0.173
Case N	10	0.07	1.72	1.20		0.216	0.060
	0		0.60	1.20		0.130	0.040
Nozzle on Airfoil	10		1.22	2.10		0.280	0.300

[16] Rate of wind, 30 m.p.h.
[a] Increase of lift, 136 per cent.
[b] Increase of drag, 85 per cent.

for the three nozzle-positions are given in Table 1. Note in Case *M*, with zero-deg. angle of attack, an example of lift reversal; the airfoil shows plus lift when either the wind alone or the jet alone is in action but shows negative lift when both are on together.

Precision of Aspirator-Jet-Principle Test

In spite of the crude nature of the test, the evidence as secured points strongly to the existence of a favorable effect on the airfoil performance when a jet of this sort is brought into action. Even if the recorded forces themselves did not point to this evidence, the action of the balance at the moment of throwing the jet into operation would of itself tend to corroborate the theory; for when, during a test at 30 m.p.h., the air-valve was opened, the lift beam was observed to swing suddenly and by an amount noticeably greater than when the valve was opened but the wind was shut off. The lift readings obtained were more significant than the drag readings, because the method of attachment of the air hose was such as to favor lift readings and to embarrass drag readings.

In the test the velocity of the jet was much greater at the lower end of the airfoil than at the top, and any favorable effect would be somewhat blanketed by leverage. The most favorable effect would occur nearer the pivot than the normal 51-in. leverage, whereas the less favorable effect due to the comparatively low velocity of the jet would occur at a greater leverage than 51-in., with the result that the recorded lift would be below the proper value.

The velocity of the jet used is estimated at four to nine times the velocity of the air-flow in the wind-tunnel. Although this required a pressure of 55 lb. per sq. in. on the air tank, this pressure dropped to 30 lb. per sq. in. at the point where the rubber hose was connected to the tube issuing from the aspirator; and this 30 lb. was

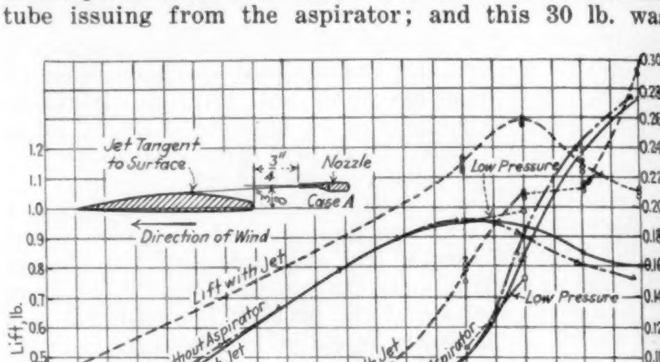

FIG. 4—LIFT AND DRAG CHANGES WITH CHANGES IN ANGLE OF AIRFOIL

Lift Is Increased throughout the Range of Angles with the Jet Directed toward the Trailing Edge of the Airfoil and an Air-Current of 30 M.p.h. The Test Was Made at McCook Field April 15, 1925, and for Comparison the Results of a Test Made Without Aspirator on Feb. 25, 1924, Are Shown. The Maximum Lift of the Airfoil Is Increased 35 Per Cent by Use of the Jet and the Drag also Is Increased

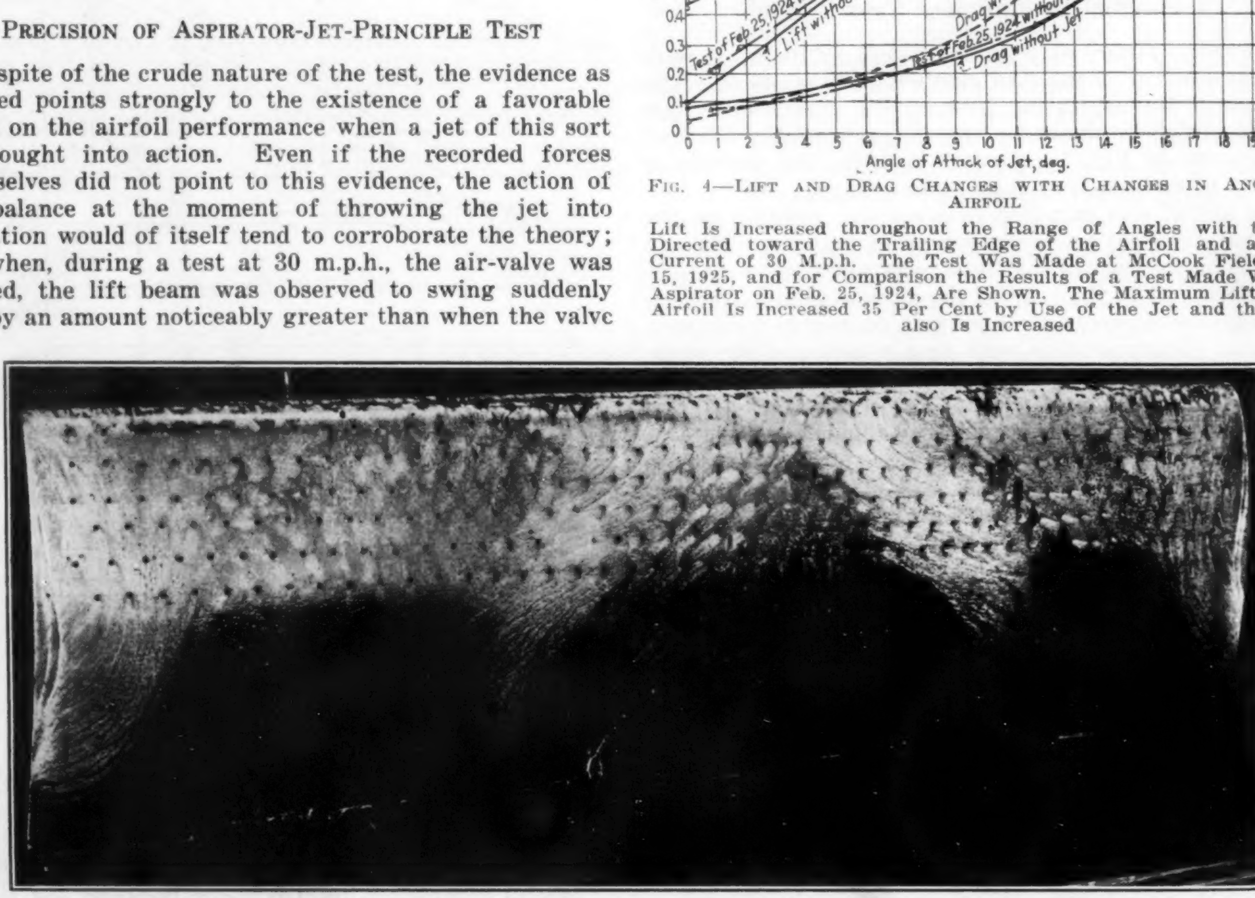

FIG. 5—AIRFOIL WITH INDUCTION-JET PERFORATIONS EXTENDED FROM TIP TO TIP

The Airfoil Was Divided Internally into Three Compartments Extending Parallel to the Span and Separately Connected to a Suction Blower by Tubes That Could Be Shut Off as Desired. Perforations Were Not Made in the Rear Compartment and Consequently No Boundary-Layer Induction Occurred over This Portion of the Wing

greatly reduced at the nozzle of the jet both by internal friction and by seven-fold expansion in the area between the pipe and nozzle, so that the useful available average pressure at the nozzle was 1.4 lb. per sq. in. as measured by a specially shaped pitot-tube. For 50 m.p.h. on this airfoil, equivalent to landing speed, the corresponding nozzle-pressure would be about 4 lb. per sq. in.; for 100 m.p.h. the corresponding nozzle-pressure would be about 16 lb. per sq. in. Note that these pressures are scaled-up values only and cannot be interpreted as the pressures to be predicted for full-scale use.

Results of aspiration tests with a 3 x 18-in. USA-51 airfoil are shown in Fig. 4. These are from test No. 144-*b* Case *A*, and show the lift and drag changes caused by a jet blowing on a conventional airfoil. The lift is increased throughout the range of angles tested. The burble angle has been deferred 2 deg. by the jet and the maximum lift increased 35 per cent, while the drag also has been increased.

Apparatus and Method for Testing Boundary-Layer Induction Principle

A hollow Clark Y-airfoil 6⅝ x 24 in. was made with its interior divided into three compartments by bulkheads extending parallel to the span. A nozzle of 9/16 in. inside diameter was provided on each compartment, and three rubber tubes led to a manifold connected to a small suction blower located outside the tunnel. Laboratory clamps on the rubber tubes were used as throttles when desired.

Perforations were drilled in the upper wall of this hollow airfoil and when the suction blower was operated the turbulent air of the boundary layer was inducted into the airfoil and discharged through the blower. The number of perforations was increased at successive stages of the test to study the effect of their relative position. At first, only the left half-span was perforated, so that one-half the wing would show the induction effect and this could be compared with the normal flow on the other half-span. The perforations were then extended from tip to tip for the tests of Fig. 5, and for the silk-streamer tests of Fig. 6. Except for the silk-streamer test, perforations were not made in the rear

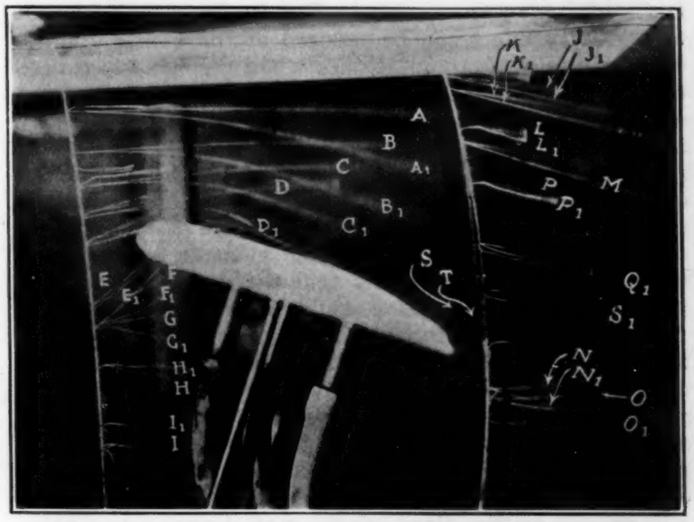

Fig. 6—Silk-Streamer Test of Air-Flow with and without Boundary-Layer Induction

The Positions of the Threads Show the Air-Flow around the Wing in the Wind-Tunnel. Threads *A*, *B*, *C*, and so Forth, Show the Streamlines with a 30-M.p.h. Air-Current and without Induction, while Threads A_1, B_1, C_1, and so Forth, Show the Streamlines with Induction. Some Threads in the "Deadwater" Region in the Case of No Induction, as between P_1 and Q_1, Have So Tubulent a Motion That No Image Is Recorded in the Film, while Other Threads, as *S* and *T*, Show a Reversal of Air-Flow

compartment, and consequently no boundary-layer induction occurred over this portion of the wing.

The model was mounted horizontally, cambered side up, in a special flow-chamber provided with glass sides for observation of the flow-lines. A mixture of lampblack and kerosene was painted on the surface. When the air current was turned on in the wind-tunnel the flow-lines recorded themselves in the black pigment after a run of a few minutes.

This new method[17] of visualizing air-flow was developed for aerodynamic use at McCook Field. It seems to depict the true flow of air, with its skin friction, along the surface studied, so long as this surface is horizontal.

On the airfoils of this test, inclined at high angles, gravity effect on the wet paint no doubt has distorted the picture somewhat in locations where the air-flow is very slow, as may be seen in the "runs" at the mid-

[17] See McCook Field Serial Report No. 2635.

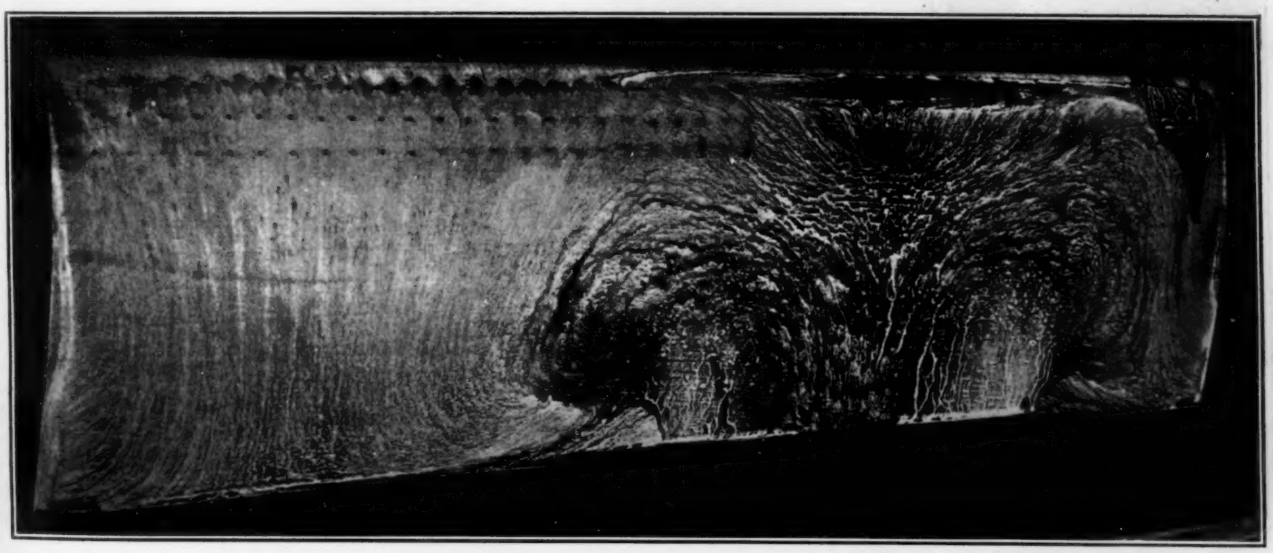

Fig. 7—Air-Flow Shown by Mixture of Lampblack and Kerosene

On a Horizontal Surface the Mixture Seems To Depict the True Air-Flow, with Its Skin Friction, along the Surface Studied, but Indicates Direction Only and Not Velocity of Flow. Normal Non-Inducted Flow Is Shown on the Right Half-Span and Flow with Induction Is Shown on the Left Half-Span

trailing edge of the airfoil in Fig. 7. It is thought that this gravity effect can be ignored at the points of high velocity, which clear up at once when the wind is turned onto the painted model. Thus any markings recorded during short fractional-minute tests, as in Fig. 5, may be relied upon. It is to be remembered that the markings indicate direction only, not velocity of flow. Actual observation of the test is, of course, superior to study of photographs, as account can be taken of the motion of the paint particles and the time element. The model was mounted in such a way that the angle of attack as well as the blower suction could be altered during test from outside of the tunnel. Before the end of each run the model was brought from its test angle to about -4 deg. to prevent smearing of the picture due to residual puddles of paint draining off downhill when the wind was shut off. The wing was then photographed without removal from the tunnel, using indirect lighting for the elimination of glare and halation. As the camera axis was oblique in the plane of the airfoil span, the photographs are in perspective with the center of the span and appear off-center and one wing tip seems smaller than the other. This should be remembered in studying the photographs, especially as the flow at mid-span is interfered with by the suction nozzles and the crank spindle, which are about 2 in. off center toward the left tip. The effect on the flow pictures of an 8 x 10-in. end-plate at the left tip was investigated and found to be chiefly local.

Besides the pictures of flow on the wing surface, photographs were also made of the flow-lines at a distance above and below the model, as in Fig. 6. Silk threads were fastened to wires rising vertically in front of and behind the airfoil about ½ ft. from the left tip. The difference in positions of these threads with and without boundary-layer induction was recorded photographically by a single exposure of the camera. During the first half of the exposure ordinary flow in the tunnel was maintained; then the induction was started by switching on the blower motor half-way through the exposure, at which time the threads changed their position to match the new flow. The angular difference between the two positions was scaled from the photograph.

Results of Boundary-Layer-Induction Tests

From the evidence of the photographs it is concluded that burble angle can be raised to 25 deg., or 10 deg. above normal, and that the benefits of boundary-layer induction are noticeable for angles as high as 35 deg., or 20 deg. above normal. It is expected that more elaborate tests will disclose further details regarding the principle, including lift and drag coefficients.

Figs. 7 and 8 show on the right half-span the normal non-inducted flow; and, contrasted on the left half-span, the flow with induction. In the photograph at the left in Fig. 8 the smoother flow due to induction through three rows of holes on the left, or lower, half-span is already apparent at an angle as small as zero deg. Fig. 7 is for the same induction conditions but at a 16-deg. angle; the flow has detached from the right half-span but clings to the left half-span, although the angle exceeds the normal burble-angle.

The three series of holes were increased subsequently to five rows, all near the leading edge; after which an improvement in flow was evident for angles up to 30 deg. Next, the middle compartment of the airfoil was perforated by three rows of holes, after which 34 deg. was attained. It was found that holes toward the front were

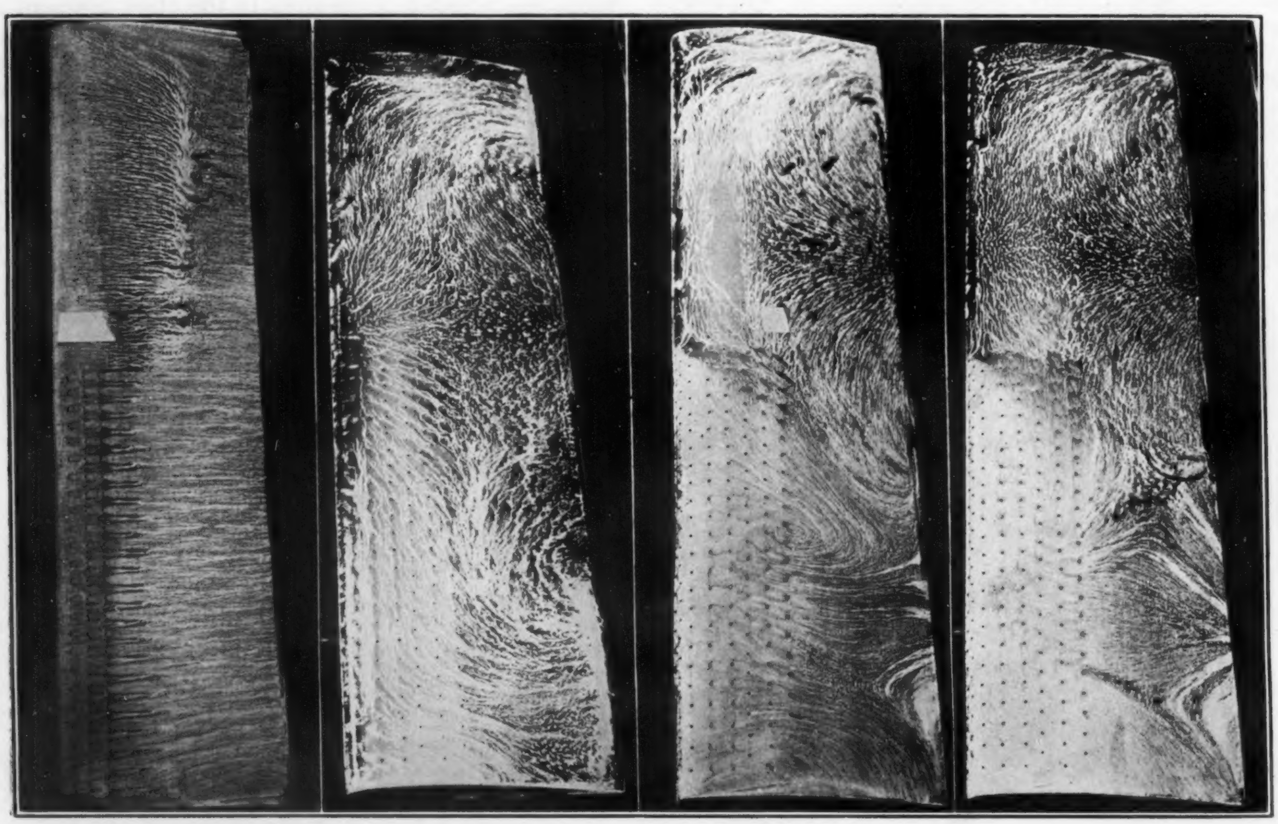

Fig. 8—Air-Flow Markings in Lampblack-and-Kerosene Paint with Variations in Angles and Induction
(Left) Flow at Zero Angle with Induction through Three Rows of Holes on Left, or Lower, Half-Span Only. (Left Center) Flow at 30-Deg. Angle with no Induction. (Right Center) Flow at 30-Deg. Angle with Induction through Eight Rows of Holes on Left Half-Span. (Right) Air-Flow at 34¾-Deg. Angle with Induction through Eight Rows of Holes on Left Half-Span in the Forward and Middle Compartments of the Wing and None in the Rear Compartment

of primary importance at all angles and that the rearward holes were not vital at low angles but became more and more important as the angle was increased.

The view at the left center in Fig. 8 shows the flow with the airfoil at 30-deg. with no induction on either half-span. For comparison, the view at the right center shows the flow with induction on the left half-span through eight rows of holes; note the vortex center near the center of the left half of the airfoil, which is evidence of a vortex with a horizontal longitudinal axis. This vortex no doubt acts as a wall to separate the burbled flow on the right half-span from the smooth flow on the left half-span.

The photograph at the right in Fig. 8 shows the airfoil at the greatest angle for which flow improvement was obtained, that is, 35-deg., with eight rows of holes on the left half-span in the forward and middle compartments and no holes in rear compartment. The vortex center of the preceding view has given place to elbow-shaped markings. The markings of the right half-span are similar, however, to those in the case of the 30-deg. angle, as shown in the left center view, where no suction was applied, but are shrunk to half-span dimensions.

It is of interest in passing to study the markings of these photographs for evidence as to the characteristics of burbled flow. The pattern in the left-center photograph is no doubt somewhat distorted by a gravity effect because the flow causing the lines is a slow secondary eddy. The markings have the appearance of a spray starting upward from the trailing edge, then curling out and down like a ram's horn as though caused by a central pair of slow vortices countering the tip-vortices. The vortex center which appears on the right-center photograph seems to be a counter-vortex matching the left vortex of the slow pair represented by the ram's horn on the right half-span. In the right-hand view is shown a tendency toward the formation on the left half-span of a separate spray, while the vortex center has disappeared.

In Fig. 5, of a short test at a 25-deg. angle with induction, the tips of the ram's horn are manifest on either side of the mid-span, but the spray starting at the trailing edge is missing; the flow follows two main paths as in the two legs of an inverted V with its apex at the mid-span of the leading edge. This figure also shows that at an angle of 25-deg. and with eight rows of holes drilled along the entire wing-span, the flow does not separate until 50 per cent of the chord is reached. This pattern may be contrasted with the left-center pattern in Fig. 8, although the latter is for a 30-deg. angle; because the non-inducted flow is about the same at 25-deg. as at 30-deg. In the latter pattern the flow separates close to the leading edge.

The silk threads in Fig. 6, for a 25-deg. angle, show the difference between the flow in Fig. 5 and in the left center of Fig. 8. The threads are lettered *A*, *B*, *C*, and so on for their non-induction position, and A_1, B_1, C_1, and so on for the case of induction. Note that some of the threads, as between P_1 and Q_1, in the "deadwater" region in the case of no induction, have so turbulent a motion that no image is recorded on the film, while other threads, as *S* and *T*, show a reverse flow.

Upon scaling-off the angles through which the tips of the threads have been shifted by boundary-layer induction, general evidence is obtained that (*a*) the downward deflection, or "downwash," above and behind the wing is increased by an amount varying from 5 to 20 deg., and (*b*) the angle of entry, or upward deflection, ahead of the wing is increased by 10 to 20 deg. Thus the effective radius of curvature of the mean flow around the airfoil has been greatly decreased.

With the airfoil at 30 deg. the threads verified the flow picture-tests; the effect of induction on the threads above the airfoil was less pronounced at this angle; the "deadwater" was more extensive, and the separation of flow was not entirely remedied.

Energy Required for Boundary-Layer Induction

To provide approximate data for calculating the power requirements of the boundary-layer-induction test, readings were taken of the aerodynamic pressure-distribution on the upper surface of the wing. To do this the suction hose was disconnected and the front wing-compartment was connected with a manometer. The wing angle was varied from zero to 50 deg. Pressures at other parts of the wing surface were not read, as they have less intensity. The maximum intensity of depression at any angle was −2.18 velocity heads.

The volume of inducted air was estimated from the blower characteristics to be of the order of 10 cu. ft. per min.

The resistance coefficient of the airfoil at a large angle of attack, say 25 deg., was taken as 0.001 in ft-lb-m.p.h. units.

For practical application of boundary-layer absorption, a blower efficiency of 50 per cent was assumed.

It followed that the power needed for the pump was about 4 per cent of the power needed for flight.

THE TRACKLESS TROLLEY IN ENGLAND

THE great advantage of the trackless trolley over the street car is its ability to deviate a distance of 15 ft. laterally from the trolley wires, which means that it can maneuver over 35 ft. of the roadway's width. It can thus discharge and receive its passengers near the curb and, when running, can pass other vehicles when necessary. That, under the circumstances, a large number of important cities should have adopted the trackless trolley in preference to the street car with its expensive track equipment is not surprising. Ipswich, for instance, has disposed of all its street cars; Keighley has done likewise; and Wolverhampton is doing so, while other cities, including Birmingham, Bradford, Darlington, Grimsby, Leeds, Oldham, Rotherham, Stockton-on-Tees, West Hartlepool and York, have substituted the trackless trolley for street cars on several routes. So far, however, the street car, by reason of its superior carrying-capacity, has not been ousted from the busier routes, although the potentialities of the six-wheel vehicle encourage the belief that the days of the street car are numbered and that its supersedure by the pneumatic-tired, well-sprung, easily steered trackless trolley is inevitable.—*Modern Transport* (London).

Merchandising Motor-Truck Transportation

By C. S. Lyon[1]

Transportation and Service Meeting Paper *Illustrated with* Photographs

ABSTRACT

THE real merchandisers of motor-truck transportation are operators who sell their services to the public. Many engaged in motor-trucking fail, however, to realize the importance of selling their services in a businesslike way. Stability of the service is in direct proportion to the strength of the supporting organization. This fact becomes more evident when costly maintenance becomes a factor or when a business depression occurs and must be weathered. Only preparedness of the supporting organization can then preserve the service. This preparedness, together with its cost, is the item most overlooked in seeking to determine the cost of the service, and is least investigated by the buyer of the service.

This preparedness does not require an elaborate shop and shop equipment, nor an abnormal profit on haulage service; but it requires a personnel that has the ability to function properly in every emergency. Automotive transportation is a production problem to as large an extent as is the manufacture of the vehicles, and the merchandising of truck service is as much of a selling problem as is the selling of passenger or freight service on a railroad. The author supports these assertions by drawing a parallel between manufacture and operation of trucks and the rendering of railroad service.

The high percentage of failures in the motor-truck haulage business is attributed by the author largely to the overzealous truck-salesman and the overfinancing of irresponsible operator-purchasers by the truck makers through extended time-payments. The keen desire of operators who have been oversold to meet their obligations has prompted them to solicit business at ruinous prices, and reputable and conservative operators have this competition against which they must contend. Before motor-vehicle transportation can be regarded as a permanent link in the general transportation system, it must be conducted on a businesslike basis, and this basis can be determined only by survival of the fittest.

Some details are given of the garage and shop facilities and the automotive equipment of the haulage company with which the author is connected. Economical location, construction and arrangement of the garage is an important feature. The use of a dynamometer for testing overhauled engines saves time and money in ways that are explained. Novel features of transportation units that have merit and have proved or promise to be economical include the use of triple rear tires of the cushion type; armored cabs suspended in ball-bearing hangers and ventilated by a suction blower; and duralumin van-bodies that weigh approximately one-half as much as conventional bodies of wood and steel.

Discussion following the paper centers mainly around the advantages of the use of the dynamometer and the triple tires; cost and possible economy of the duralumin body; effect on maintenance cost of overloading vehicles 100 per cent, and probable effect on profits at present haulage rates if laws that limit the maximum gross weight of vehicle and load and the gross weight on any one axle were enforced in all States.

MOST persons look upon the manufacturers of motor-trucks as those who merchandise transportation; to me, the transportation merchandisers are operators who sell their services to the public. This field is occupied by many who are engaged in motor-trucking but who fail to realize the importance of merchandising their services in a business-like way. This has resulted in a condition that will, no doubt, require some time to overcome. Such merchandisers have only one product to sell, that is, service, and their productive machines are motor-trucks which are somewhat expensive masses of refined steel. To sell this service properly, concentrated effort must be directed toward the selection of men and equipment.

As in any other sound business, the stability of automotive transportation-service is in direct proportion to its supporting organization. This fact may not be so apparent during the first few thousand miles of operation with new equipment and prosperous business conditions, but later, when costly maintenance becomes a factor or when a business depression has to be weathered, only the preparedness of the supporting organization can save the service. It is most unfortunate for the industry that this preparedness, together with its cost, is the one item most overlooked in determining the cost of the service required and is least investigated by the buyer of the service.

This preparedness does not mean an elaborate shop fitted with every form of modern machinery and equipment; neither does it mean an abnormal profit on work performed. It does mean a personnel with ability to function properly in every emergency, because automotive transportation is as much of a production problem as is the manufacture of the vehicles themselves, and its merchandising is as much of a problem as the selling of passenger or freight service on any railroad.

Parallel between Motor-Vehicle and Railroad

To illustrate my point more clearly, let a parallel be drawn between the motor-vehicle and the railroad:

> *Affecting Production.*—Assume that in the manufacture of the vehicle a failure of an important productive unit occurs and that no provision for reserve set-up has been made. The result is that customers become dissatisfied. Suppose that in transportation by rail a failure of a motive unit occurs and there is no reserve; the public would be dissatisfied. Similarly, in transportation by motor-vehicle, the failure of an automotive unit means a dissatisfied customer, who, unfortunately for the operator, is not so lenient as the purchasers of vehicles or the rail-using public; hence the operator needs a reserve.

[1] Vice-president and general manager, Motor Haulage Shop & Garage Corporation, Brooklyn, N. Y.

Affecting Reliability of Service.—Suppose the service stations were taken away from the motor-vehicle manufacturer or the repair-shops from the railroads; how could either support the commodity it sells? Transportation by highway requires facilities for the support of its service that are commensurate with those of the railroad.

Affecting Revenue.—Suppose that the vehicle-manufacturer were deprived of his sales organization or the railroads of their solicitors, and that all advertising were eliminated; who and what would produce their flow of business? Highway transportation requires as much skill, if not more, to sell its service at a profit as either the vehicle builder or the railroad.

Affecting Return on Investment.—Suppose both the manufacturer and the railroad eliminated their accounting, cost, statistical and many other departments, which to many seem unnecessary in the highway transportation-business; or suppose that insurance, legal advice, research, and financial studies were all thought unnecessary; how long would either the manufacturer or the railroad exist? Highway transportation has as many problems as either and, if it is to exist, must be supported with an equally intelligent personnel.

them to solicit business at ruinous prices. Consequently, the reputable and conservative operator has this unfortunate competition with which to contend.

Before motor-vehicle transportation can be regarded as a permanent connecting-link in the general transportation-system it must be conducted on a businesslike basis. This basis can be determined only by survival of the fittest. Whether this survival will be by consolidation or by large independent operators, I do not venture to discuss. I merely want to bring to attention these high points as the company with which I am connected has seen them while engaged in motor-truck haulage with 168 productive units in and around the Greater New York metropolitan area. We have seen many haulage men come into and go out of the field, and I believe that most of the failures can be attributed largely to the two factors I have tried to depict as we see them in the motor-truck transportation business.

Economical Location and Construction of Garages

The accompanying illustrations show the garages of the company with which I am connected and some of

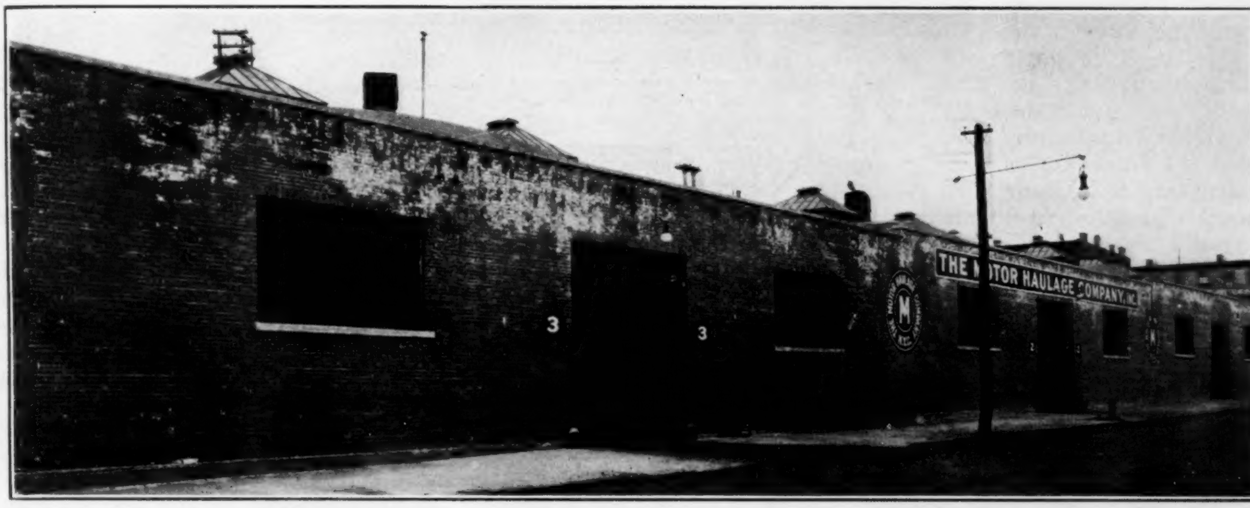

Fig. 1—Brooklyn, N. Y., Garages for Heavy-Haulage Automotive Equipment

These Are Located on Low-Priced Land within a Short Distance of the Properties of the Operator's Principal Customers. Floors Are All on the Ground Level, Which Eliminates Cost of Elevators and Their Operation. Construction Is of Low-Cost Type, Well Lighted from Above, and Entrances Are Wide and High. Five Garages Are Embraced in the Group and Each Has Capacity for 25 Vehicles. The Floor Area Is Wide, and High Curbs along Either Side Prevent Vehicles from Being Backed against the Walls. The Floor Is Unobstructed by Roof-Supporting Posts

Supervision and Dispatching.—Railroads are expected to meet the demands of the public as to both passenger and freight service that is safeguarded by competent dispatching and supervising. This supervising and dispatching must be maintained by a motor-carrier over the highways if he wishes to assure his customers of service that will meet the demands of the public.

Failure Due to Unbusinesslike Methods

I do not know of any transportation business that has a higher percentage of failures than motor-trucking. This condition may be attributed largely to the motor-truck manufacturer and his method of merchandising. The desire to meet competition has resulted in over-financing irresponsible persons who have been told by zealous salesmen that their product can be operated at a certain cost, which does not take into consideration the service expected by customers of the service. Extended time-payments have resulted in the overpurchase of vehicles by many who think that motor-trucking is a sure money-making business, and their keen desire to meet their obligations to the manufacturer has prompted

their equipment and also some of the haulage units operated by the company. Much time and study has been devoted to the subject of economical location and construction of the building shown in Fig. 1, which has been occupied about 3½ yr. As 80 per cent of the garage area is taken up in the storage of motor-vehicles at night, the item of storage cost, which must be regarded as an overhead expense, deserves consideration. For this reason an endeavor was made to locate a piece of property within a short working-radius of the company's larger customers that would afford the necessary area for storage of vehicles at a minimum cost on the ground level, thereby eliminating the cost of operating and maintaining elevators and other items of cost that had been incurred in the use of rented buildings

The building as shown is on Amity Street in Brooklyn, N. Y., and extends through to Congress Street. Five garages of approximately 10,000 sq. ft. each are embraced in the buildings and each have a capacity of about 25 heavy-duty vehicles. A total absence of roof-supporting posts leaves the floor space clear, and high curbs at some distance from the wall at either side eliminate the

possibility of drivers bumping their trucks against the walls. The floors have a slight slope toward the center to facilitate rolling vehicles out for a washing at night. Drivers receive their work instructions for the day from the dispatcher's office and are required to make out and turn in at night reports covering the day's work, which provide the information on which customers are billed. The reports are checked-up by "runners" assigned to various territories in which the trucks are operated. They number from 200 to 300 a day and are checked by noon the following day and rechecked against the runner. These reports percolate through the organization 100 per cent, particularly with reference to the mechanical work necessary to be done on the vehicles at night to make them serviceable for work the next morning.

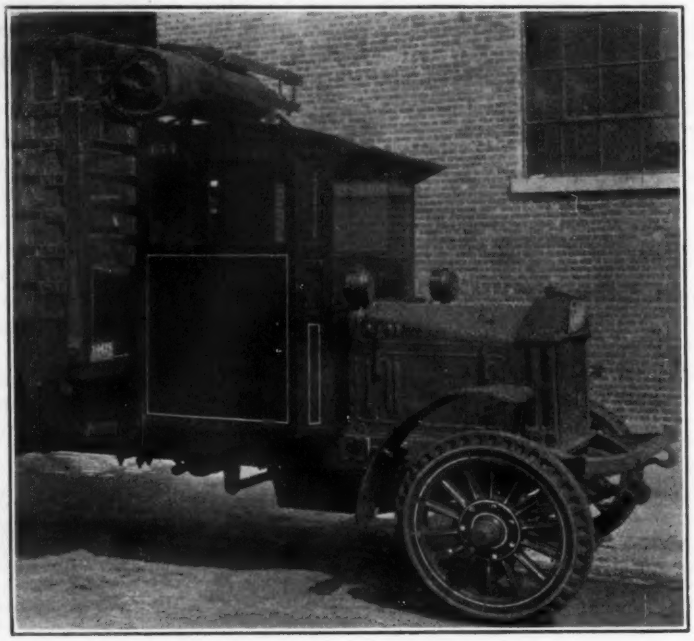

FIG. 2—RACK TRUCK WITH ARMORED CAB
Twenty-One Trucks Equipped With Armored Cabs Are Used for Hauling Valuable Merchandise in New York City. The Cabs Weigh 1000 Lb. and Much Trouble Was Experienced with the Cabs Wrenching Apart and the Chassis Frames Breaking. This Difficulty Has Been Overcome by Mounting the Armored Cabs on Ball-Bearing Hangers

The portion of the building used for maintenance and repair is well lighted and ventilated, has an overhead crane for the removing of bodies and rear ends and for the unit-change system of repair. All major repairs on the power units are made in the engine-assembly shop, where an average of about 25 engine overhauls are made per year for the entire fleet. Included in the shop equipment is a small electric dynamometer, a large tire press and a washing-solution tank for parts. We have found that a solution of trisodium phosphate and soap powder is fully as effective for cleaning purposes as a compound formerly used and for which we paid 10 to 12 cents per lb. A full description of the garage and its equipment, the haulage units, the organization and its method of management was published in January, 1925, issue of THE JOURNAL[2].

While to some it may seem ridiculous for a motor-haulage company to use a dynamometer, we have found in several years' use of the dynamometer that it has eliminated more lost truck-time than any piece of apparatus we have seen. The conventional way of overhauling an engine is to put it in the truck and run it carefully for 400 or 500 miles, but when we released a truck with an overhauled engine we wanted it to be productive at once and could not be handi-

[2] See THE JOURNAL, January, 1925, p. 62.

FIG. 3—TRACTOR AND TRAILER FITTED WITH TRIPLE REAR TIRES
These 14-In. Wide Tires Give Better Traction on the Inclines of the East River Bridges in New York City When the Bridge Surface Is Slippery, and Have Given Nearly Three Times the Service Mileage Obtained from Single or Dual Rear Tires. The Operating-Company Has Standardized on Cushion Tires for Tractor Rear Wheels

capped by being limited to loads of only 3 tons instead of 12 tons. When we take an engine off of the dynamometer, it is ready to go into a truck and to perform with a reasonable degree of efficiency for 25,000 to 30,000 miles.

An advantage of the dynamometer is shown by an experience we had some time ago. Several vehicles of a popular make were purchased and after three weeks in service the drivers complained that they were slow on pick-up and did not perform as they should. At our request an engineer of the company from which the purchase was made came to the shop and inspected the engines thoroughly, changing the carbureter and magneto adjustments, checking-up on the grinding of the valves, and so forth, but the vehicles did not perform as the other vehicles did. After several months of operation, one of the engines was removed and placed on the dynamometer, and developed only 32 hp., although the manufacturer rated its capacity at 54 hp. The general service manager of the company came to the shop and checked the opening and closing of the intake valves, which were found to be correct, and it was assumed that the rest of the valves also were right. The engine has integral cams and shaft, and when asked if there was a possibility that the timing of the other valves could be wrong, the service manager said that the cams were ground on a cam generator and could not be wrong. After working about 3 days on the engine, changing the carbureter and manifold, and the like, I finally checked each cylinder as to opening and closing of the exhaust and intake-valves and found that the intake-valve on one cylinder was closing about 80 deg. after bottom center on the upward stroke of the piston. The camshaft was therefore removed and checked-up and it was found that the cam was ground improperly. Cams for two of the other cylinders also were found to be wrong, and were honed to the right contour. When the shaft was put back and timed for the standard valve-setting, the engine developed 56 hp. on the dynamometer. It was then reinstalled in the truck and is today one of the best engines we have.

A spray washing-outfit that was installed for washing vehicles has proved very successful. A spray of water and compressed air is played on the body and chassis through a nozzle, and we find that if the water temperature is not allowed to exceed 140 deg. fahr. at the nozzle the chassis is cleaned thoroughly with no bad effect on the varnish. A chassis can be cleaned thoroughly for painting in about $3\frac{1}{2}$ hr., whereas formerly a man spent from 1 to $1\frac{1}{2}$ days cleaning the chassis by hand and even then was not always careful. Prior to installation of this system of washing, a number of solutions were tried for cleaning the chassis. They took off dirt and grease but they were not a success, as the paint showed bad effects from the solutions after 6 to 8 months.

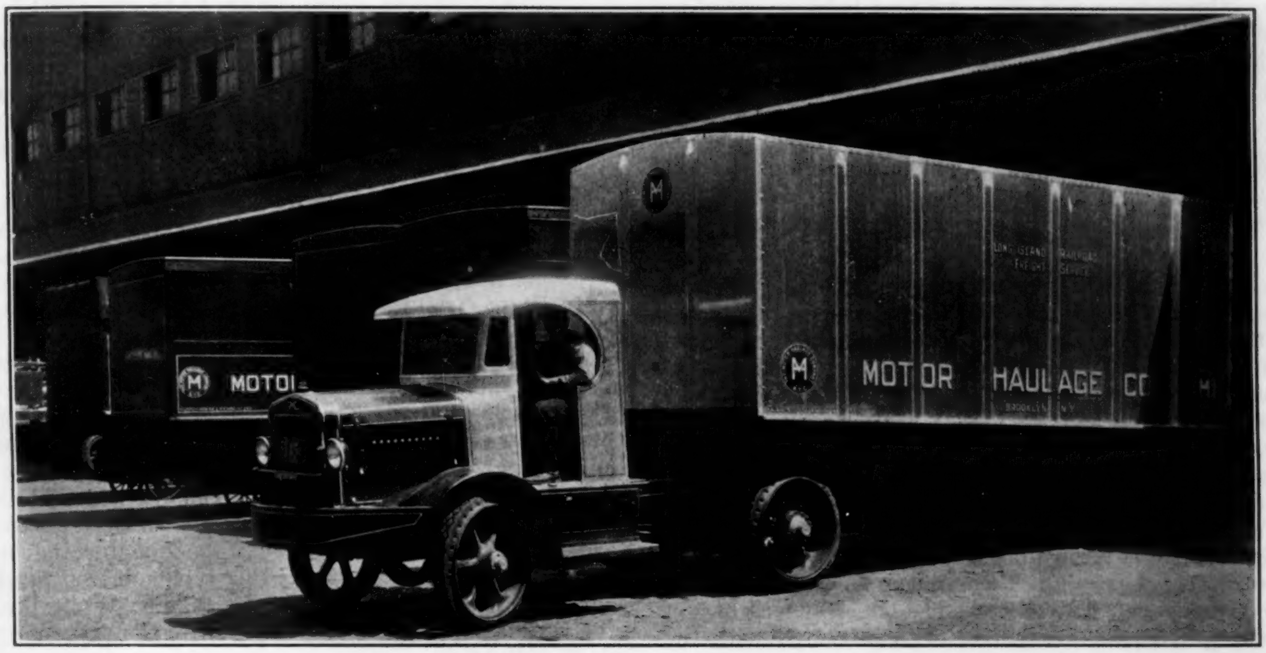

Fig. 4—Armored-Cab Tractor and Duralumin Van-Body on Semi-Trailer
The Van Body Is 20 Ft. Long, 8 Ft. Wide and 7 Ft. High. It Weighs 2750 Lb. as Against a Weight of 5400 Lb. for a Conventional Wood-and-Steel Body. Although Not Painted, It Looked as Well After 6 Months of Service as When New and No Complaints of Glare from Reflected Sunlight Had Been Received. The First Experimental Body Cost \$1.550 as Against \$1,000 for a Composite Body

Armored-Cab Troubles Overcome

Some improvements in the hauling equipment of our company will no doubt be of interest. The armored cab on the rack-truck shown in Fig. 2 is about 2 yr. old. We have about 21 trucks equipped with armored cabs that are used for hauling tobacco, silks and other valuable goods in New York City and we have had a great deal of trouble with the cabs. The weight of an armored cab is approximately 1000 lb. With the aid of the motor-truck manufacturer and the body-builder we have endeavored in a number of ways to suspend the cab so that it would not be wrenched apart within a period of 1 yr. as the result of its own weight and the road jars. The cab manufacturer guaranteed that they could build a cab that would stand up for 3 yr. but they made the cab so rigid and attached it so rigidly to the frame that unusual frame breakage resulted. Upon learning then of the Harper hanger, which is a ball-bearing arrangement, we put this device on a number of cabs and have found, after the vehicles have been in use from 6 to 8 months, that with the ball-bearing feature the cabs are as stable today as when they were first mounted. These cabs,

which weigh about 1000 lb., cost about $1,000 apiece.

Last year the question of ventilating the cabs arose. By placing thermometers in them it was discovered that the temperature inside the cabs averaged 14 deg. more than the outside temperature and, as the atmospheric temperature in New York City sometimes reaches 90 deg. in the summer, this meant 104 deg. inside the cab, which was unendurable for the driver. Now we are working with a motor-truck manufacturer who is installing a Sirocco fan in the cabs to draw out the warm air. In a test of one of these cabs after it was delivered, the inside temperature was reduced in 1 min. to only 2 deg. above the outside temperature.

Fig. 3 shows a tractor equipped with air-brakes and triple rear tires. A great many runs are made by trucks lightly loaded or empty and considerable difficulty has been experienced in pulling up the inclines of the Manhattan, Queensboro and other bridges between Brooklyn and New York in certain months of the year when good traction was not afforded on the bridge surfaces. The triple tire was adopted to give better traction and we have found that they give very satisfactory mileage. Some have run 35,000 miles as against 12,000 miles of service given by dual tires. I am therefore enthusiastic over the triple tire for tractor work, particularly where bridges that are often slippery must be crossed.

Duralumin Van-Bodies Save Weight

We use 29 trailers in a freight-service installation operating in the Long Island Railroad interchange between Pier 22 and Flatbush and for the elimination of peddler trains from Long Island City on the north shore of the island as far east as Port Washington. The bodies of these trailers are 20 ft. long, 8 ft. wide and 7 ft. high and are of the van type, as the class of general merchandise handled permits the use of the enclosed type of body. The body shown in the foreground in Fig. 4 is particularly interesting. As we began the use of van bodies of this large size the weight became considerable; the conventional body fabricated of wood and steel weighs approximately 5400 lb. We therefore contracted with the Aluminum Co. of America to design and fabricate bodies of the alloy metal commonly known as duralumin. While this body has the same cubic capacity as the other, its weight is only 2750 lb., or only slightly more than one-half that of the wood-and-steel body. After the first of these bodies had been in service for approximately 6 months on a 24-hr. schedule, its condition was found very satisfactory. Although no paint was put on it, it looks as well today as the first day it went into service. No complaint has yet been received of glare caused by reflection of sunlight. The front end is protected by a bumper and the rear end by a rope net covered with a curtain. This net is very effective for holding small parcels.

THE DISCUSSION

QUESTION:—What is the comparative cost of the duralumin and the composite wood-and-steel van bodies?

MR. LYON:—The conventional body fabricated of wood and steel and with the conventional roof costs $1000, painted. The experimental alloy body cost $1550, but as it required a great deal of engineering and some difficult work, this figure should not be taken as the price that one might expect to pay for subsequent bodies.

F. C. HORNER[3]:—What do you think of the future possibilities of the duralumin type of body for the kind of work in which your company is engaged?

MR. LYON:—We have been greatly encouraged by the performance of this alloy body and are now negotiating with the Aluminum Co. of America to supply us with standard duralumin sections that will enable us to fabricate not only van bodies out of this metal but also rack bodies, as we are interested in waste reduction. We now have in operation several bodies equipped with duralumin carlines, or cross members, as an experiment to see if they will withstand the overloading we give them. Our 8-ft. bodies have an extreme overhang of 30 in. beyond the outside frame-channel and we have had some trouble with breakage of wooden cross members due to loads not being evenly distributed.

Dynamometer More Than Pays for Itself

N. B. BALLANTINE[4]:—Can you give an idea of the approximate cost of a dynamometer such as you have?

MR. LYON:—The original cost was about $5,000, I believe, including the motor-generator outfit.

MR. BALLANTINE:—Do you test every overhauled engine?

MR. LYON:—Every engine is thoroughly overhauled after it is removed from the chassis and is then tested. We require that it must develop its maximum horsepower before it is released for reinstallation in the truck.

MR. BALLANTINE:—What is the approximate cost for labor and power for making such a test?

MR. LYON:—We have some very accurate cost figures on that; the average is about $12.50. Fortunately we have a very low rate for electric current in New York City and we run the engine for from 6 to 12 hr., depending upon whether a reground crankshaft and pistons are put in, and start turning at 300 r.p.m. and finish at about 900 r.p.m. It is then run under its own power and the electric current turned back into the line for industrial purposes. The engine drives the dynamometer for 3 or 4 hr. and a horsepower reading is taken. While the engine is thus being jacked-in, one man in the dynamo room takes care of the ignition, carburetion and other parts and merely glances occasionally at the engine and the thermometer and notes the water temperature.

R. E. PLIMPTON:—Would it be worthwhile to use a chassis dynamometer in addition to the one for testing engines?

MR LYON:—We would not consider the use of a rear-wheel dynamometer because of its expense, and in the overhaul jobs I do not attach much importance to testing the transmission, clutch and rear end if they are assembled properly. We pay especial attention to the powerplant.

CHAIRMAN A. J. SCAIFE:—How large need a fleet be to warrant expenditure for such a dynamometer equipment?

MR. LYON:—I should not consider the installation of a dynamometer for a fleet that requires less than 25 engine overhauls per year. Prior to the installation of this dynamometer, we used the typical belt jacking-machine with a cradle, but invariably after an engine was reinstalled and sent out it was brought to the garage for readjustment of the valves in 4 or 5 days. This waste of time and effort is eliminated by testing the engine on a dynamometer and making all adjustments so that when it is reinstalled in a chassis it is a fully productive unit from the day it is released. Our only medium of revenue is the earning capacity of the vehicles.

J. F. WINCHESTER[5]:—We have a dynamometer in our operation that cost from $3,500 to $4,000. The invest-

[3] M.S.A.E.—Assistant to vice-president, General Motors Corporation, New York City.

[4] Assistant to president, Seaboard Air Line Railway, Baltimore.

[5] M.S.A.E.—Superintendent of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

ment has been repaid many times over in the 2 to 3 yr. we have operated the outfit by the elimination of difficulties we previously encountered in being obliged to test the engines on the road after they had been overhauled. Now we know positively before the engine goes back on the road exactly what it will do and there is no road testing. Before the dynamometer was installed an engine was overhauled, jacked-in under belt power, put into the chassis and then taken out on the road. In many cases an overhauled engine had to be taken out again and readjustments made. This caused a great deal of expense that we do not encounter now. The original cost of the dynamometer is small by comparison with the large amount of money saved over the old method of operation.

With reference to the duralumin body, it is logical to assume that if one can carry 1 ton greater pay-load than with the old type of body, even an extra cost of $500 would not be an unwarranted investment.

As for the additional mileage obtained with triple tires as compared with single or dual tires, it would be of interest to know whether the same type of tire equipment was used in both cases because, if a change is made from one make to another make, results may be obtained that are not entirely comparable.

C. M. MANLY[6]:—Is the figure of 4000 cu. ft. per min. of air removed from the truck cab by the Sirocco fan correct?

MR. LYON:—The capacity of the fan is approximately 4000 cu. ft. of air per min. but provisions are made to restrict the air-flow by means of a casing with a shutter.

FIELD FOR DIFFERENT TYPES OF VEHICLE

MR. HORNER:—Have you been able to work out any formula, either definite or approximate, for determining the place for the electric truck, the gasoline truck, and the tractor and semi-trailer method of handling heavy haulage?

MR. LYON:—We have found the electric truck very economical for haulage in downtown New York City and around the piers where the average mileage per day is about 21 miles. Later when these trucks were put on a heavier carrier-line and operated from 30 to 32 miles a day for a period of 4 months, we found that when they exceeded 25 miles a day with the same tonnage that the drivers worked overtime. The drivers are paid the standard union wages of $6.66 per day and $1 per hr. for overtime. The increased labor cost of $1.50 a day more than offsets the economic advantage of the electric truck and we therefore confine it to loads of from 3½ to 5 tons and an operating mileage of 25 miles per day.

We have found the tractor and semi-trailer adaptable to heavy work at the piers, such as unloading machinery, in which work we carry from 18 to 20 tons per load. Where we can enjoy the advantage of a drop movement we are operating six semi-trailers to two tractors on some of our installations.

We do not venture to overload the conventional truck beyond 12 tons but actually load them to from 10 to 12 tons. When we started in the business we stopped a driver if we caught him with a 100-lb. overload on a 5-ton truck and made him take off the extra weight, but today, because of competition and the lack of appreciation of the service, we severely criticise the loader if he does not put on 10 tons, as it is necessary to obtain a reasonable profit on the money invested. On our rail-road operations I think we have the largest single unit in operation east of the Mississippi River.

We have gone through a process of change in body design, starting with the conventional rack-body, then going to an enclosed panel-body with an elevating top to permit the loading of bulky goods, such as furniture, and covering the load with tarpaulins, and after 1 year's operation of these, going entirely to the enclosed van body.

For interchange, interline and interstation work, we have found the tractor and semi-trailer the most adaptable equipment. We have considered the use of detachable bodies but, unfortunately, circumstances surrounding the operation do not permit of their economical use. When an occasion presents itself, we may coordinate the detachable body and the tractor and trailer to avail ourselves of their advantages.

MR. WINCHESTER:—The bodies you are now building afford no opportunity to load and unload from the side.

MR. LYON:—The van bodies are used solely for big-terminal work and, because of congestion at the platform and the limited platform space, the trailers must be placed close together. This does not permit side loading. Provision has been made for this, however; every body is built with right and left sidedoors, as we believe it will be only a short time before local ordinances will be passed in New York City forbidding tailboard delivery.

MR. WINCHESTER:—If delivery is made at the side, the driver can save time in maneuvering the truck or trailer into position for tailboard delivery.

MR. HORNER:—This problem has puzzled me for a long time but I think Mr. Lyon has hit the keynote; conditions and circumstances of the transportation requirements govern the type of equipment used.

Do you use mileage recorders on your vehicles, and if so, with what success?

MR. LYON:—Every vehicle is equipped with a mileage-recording device and each driver must turn in a mileage record. If, because of the failure of the recording device, the driver is unable to report his exact mileage for the day, his run is checked and the mileage figured within 1 per cent, but no vehicle is permitted to leave the garage in the morning unless its metering device is registering properly. In addition to the driver's report, the night oil-man takes the hub-odometer reading of each truck, as the oil in the engine is changed absolutely on a mileage basis that varies with the age and condition of the vehicle and the nature of the service in which it is used.

HOW EQUIPMENT SUFFERS FROM OVERLOADING

A. W. EINSTEIN[7]:—In making the change in policy to overloading, was the design of the springs changed and does the overloading have any material effect on the cost of maintenance of the fleet?

MR. LYON:—It was necessary to increase the capacity of the springs and also in many instances to reinforce the frame of long-wheelbase chassis to avoid anticipated breakage of the frame structure. The effect on the vehicles of the change in policy from conservative loading to abuse, so far as we have been able to determine, is reflected by the following comparison:

Twenty-one Packard Model-EF trucks were purchased in 1920, of which 10 were placed in service on Long Island and 10 in work on runs from New York City to Piedmont, a distance about equal to the Long Island run. The trucks on Long Island drew four-wheel trailers and hauled an average load of 10 tons, of which 7½ tons

[6] M.S.A.E.—Consulting engineer, New York City.

[7] M.S.A.E.—Manager, Retail Delivery Association, National Retail Dry Goods Association, New York City.

was on the trailer. These trucks are now coming in for major overhauling. In checking-up the engines, we find that, while some of the cylinders and crankshafts may show 0.006 or 0.007 in. more wear than others, all are so badly worn as to need grinding. Where four-speed transmissions are used in the vehicles that are grossly overloaded, the third-speed gear is replaced, on a mere estimate, about 20 per cent oftener than in the trucks that are loaded to only 5 or 6 tons. We have had no trouble with the rear axles; after operating the trucks from 35,000 to 40,000 miles, an inspection of the worms in the drive showed them to be in condition for probably an additional 30,000 or 40,000 miles.

Types and Sizes of Tire Used

MR. HORNER:—With reference to the triple tires used on heavy-duty vehicles, can you state the relative merits of cushion and semi-pneumatic tires for the type of work in which your company is engaged?

MR. LYON:—We have no equipment fitted with pneumatic tires except ¾-ton trucks and similar light vehicles. We have used Goodrich semi-pneumatic, Overman cushion, and the new Firestone hollow-core tires. We cannot calculate in dollars and cents the reduction in tractor maintenance due to the use of cushion versus solid tires. We have used triple Overman Model No. 1-36-47 cushion tires for 4 yr. and have had splendid results, as they are giving a mileage of 35,000 miles. We also equipped tractors with triple conventional solid tires and found it necessary to change these around on the wheels after they had run from 13,000 to 14,000 miles. We have standardized on Overman cushion tires for rear-wheel equipment on tractors.

MR. MANLY:—If maximum-vehicle-weight laws, such as the one that exists in Connecticut, were rigidly enforced, how much would your rates have to be increased to enable you to perform the same service and make the same profits?

MR. LYON:—We do not operate at all in Connecticut. We operate in New Jersey a great deal and our revenue there has increased approximately 40 per cent due to adoption of the triple tires on tractors and semi-trailers. After a great deal of discussion, J. B. Dill, the commissioner of motor-vehicles, finally consented to recognize the 36x6-in. triple tires and permitted us to operate in New Jersey with heavy loads on tractors and semi-trailers.

MR. MANLY:—If you were required in New York State to observe a law such as that in Connecticut which limits the maximum gross-weight of vehicle and load and the maximum axle-weight regardless of width of tire, would this not have a material effect on either the rates you charge or the possibility of your staying in business?

MR. LYON:—I do not believe the triple tires would permit us to increase our pay-load capacity in Connecticut. I think the law in that State fixes the maximum weight regardless of tire equipment, although the weight per inch of tire is also specified.

MR. WINCHESTER:—As I understand the situation, you have a truck of registered load capacity and a certain type of tire equipment. Formerly you carried 5 tons on this truck but now carry 10 tons, or 100-per cent overload. If 5-ton loads were carried at your present charge, would the operation be economical in places where 10-ton loads are now carried?

MR. LYON:—No.

WINNERS WANTED

ONE of the first steps toward better training for useful careers in industry and engineering is to interest the right boys and to pick them out of the multitudes seeking admission to colleges and trade schools. Other improvements also in our system of engineering education have been found desirable by a 3-years investigation recently completed by the Society for the Promotion of Engineering Education with the cooperation of more than 100 engineering colleges, the engineering societies, the Carnegie Corporation of New York, the Bureau of Education, the National Industrial Conference Board, and a number of industries.

Our engineering colleges, in the main, have been doing good work. Science, engineering practice and industry have, however, in recent years, been making rapid and long strides forward. The wealth of our citizens has greatly increased. New demands are being made upon our educational system. Adjustments became necessary in engineering education. Leaders in the colleges and the engineering societies determined to find out what was needed and how to go about meeting these needs.

Investigation in this and other countries brought together a large body of facts, but very little practical benefit would have followed if the work had ceased at that point. One or two notable earlier investigations failed of fruition for lack of organized endeavor to put the findings to use. Consequently, the Society for the Promotion of Engineering Education with the support of the colleges; the American Societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers; Engineering Foundation; the engineering press; and numerous industries and individuals has entered upon 2 years of further active endeavor to put its gathered facts into use.

Some of the objectives are:

(1) Better admission, teaching and placement methods and reduction of costly "mortality" in engineering colleges
(2) Broader and simpler curricula, with more emphasis on principles and on economic aspects of engineering
(3) Better provision for attracting and training men competent to be teachers
(4) Better adjustment between college education and industrial experience
(5) Improved means for training in specialties and business practices after graduation
(6) Closer bonds between colleges, engineering societies and industries
(7) Better balance of facilities, for vocational education, technical education and professional education in engineering
(8) Economies of human effort and of funds, resulting from these betterments

Further information, including reports of the investigation, will be supplied upon request addressed to Chairman Scott, Director Wickenden, or the Engineering Foundation, at Engineering Societies Building, 29 West Thirty-ninth Street, New York City. A well-balanced engineering education is being found one of the best preparations for many responsibilities in industry and business, as well as the professions. Better graduates are essential to better industry and to the general welfare. The future of our industries will be determined by the capability of the men who lead them.—Alfred D. Flinn, director of Engineering Foundation.

Fields for Young Engineers in the Automotive Industry

THE following four papers were delivered at a Student Meeting held by the Metropolitan Section the evening of Feb. 16, 1927, at the Engineering Societies Building, New York City. The object of the meeting, which was the first Section Meeting of its kind, was to stimulate interest in automotive work among students taking engineering courses in educational institutions in the City and the surrounding metropolitan territory; to picture to the students the size and ramifications of the industry, and to show the many kinds of technical workers it requires.

A copy of each speaker's edited paper or transcript of his remarks was submitted to him for approval or correction before publication. Taken together, the papers present a good picture of the opportunities afforded for young men with engineering training in car producing companies, parts companies, research organizations, and in the operating and maintenance fields.

In the paper by David Beecroft the development of the industry is reviewed briefly and it is shown that it has passed successively through the experimentation and development stages, into the quantity production stage, and is now in the era of research, refinement and cost reduction.

The motor-vehicle industry is now the largest industrial industry of the Country and the production of cars and trucks in 1926 aggregated a wholesale value of $3,163,000,000. If the value of tires, component parts and accessories is included the aggregate production of the industry was approximately $5,000,000,000. The extent to which it and the allied industries are interdependent is shown. Statistics are given to show the huge organization spread over the Country to sell the 4,500,000 vehicles produced annually and the even greater organization required for the maintenance of the 22,000,000 motor-vehicles in use. That the industry must continue to expand is indicated by pointing to the great public works that are being carried on for the improvement of traffic facilities.

President Hunt, of the Society, defines design and research, shows their relation to each other, the opportunities open to young men in these branches and the ability and personal characteristics that are essential to success. The organization of personnel and work in the engineering departments of large car-producing and large parts manufacturing companies and of a research division of a car company is shown by charts and described. The author tells the range of wages or salaries paid for the different kinds of work or positions, and predicts that the development of new materials and research will result in extensive design changes. Therefore, he concludes, a young man can enter the field of design and research with the expectation of plenty of work throughout his career, and of good financial rewards and the satisfaction that comes with worthwhile technical work.

R. E. Plimpton deals with the growing size and importance of motor-truck and motorcoach operating organizations and the demand for technically trained young engineers in this field. The possibilities of a young man working his way up rapidly to an executive position from the lowly position of a mechanic in the maintenance department or of a driver of a motorcoach are depicted. Some of the larger operating-companies are equipped with uptodate machinery and other facilities for production of replacement parts and even complete vehicles as well as for repair work, while in the operating division the drivers come into direct contact with the public. A trained personnel is required to man these maintenance and operating divisions, and if the young engineer is willing to work his way up and has the vision to see that motor transport will become one of the most important of all transportation industries, this field offers a future that is comparable with that offered in research, design, production and sales engineering.

John Younger tells the prospective engineering graduate what is necessary for him to know and do to prepare himself to become an executive in the automotive industry. He shows that knowledge of materials, stresses and design is no longer sufficient, but that in the present era of large-volume production and keen competition it is necessary to study cost accounting, economics, work analysis, standardization, simplification and waste elimination, and the human material with which he must deal. The beginner in a factory is told to use imagination, project his thoughts into the minds of the purchasing agent and the chief engineer, and to study the men around him. Real study is not ended when a young man leaves college but, for the neophyte who would become general manager, begins when he takes the great step in life from the educational institution into the industrial world.

THE AUTOMOTIVE INDUSTRY AS A FIELD FOR YOUNG ENGINEERS

BY DAVID BEECROFT[1]

THE automotive industry is one of the most attractive industries of the age. Perhaps in some respects the automobile may be yielding its position a little to aviation, but when we think of the ages that man waited for a self-propelled vehicle for individual transportation, it is not surprising that such a mammoth industry could be developed in a period of less than a generation. Our industry has been fortunate, too, in being so well advertised and in having in it such conspicuous characters. It has, perhaps, the greatest industrialist the world has ever known and he is one of the greatest missionaries for the industry.

If we want to find the earliest roots of our industry,

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we must go back to 1820, when certain constructions, such as the differential, were developed and brought into use. In 1827 the layout of steam motor-vehicles embodied the chassis arrangement as we know it today; features of rear-axle design and even gear or shaft-drive as we know them were conceived at that time.

If we were to trace the history of the internal-combustion engine, we should find as far back as 1845 very complete designs, but, as gasoline did not come upon the market until about 1859, not much development of this type of engine was had before the latter date.

The period from 1893 to 1903 was one of broad experimentation and pioneer work in this Country with steam, electric and gasoline-vehicles; then this situation began to clear rather definitely and it became evident that the gasoline-vehicle would take the lead. Soon the car with the vertical four-cylinder engine became the accepted type.

Eras of Development and Construction

The first 12 years of the present century were the great development years in which the various component units of the automobile were brought to a fairly high standard of functioning. Only a few parts have been added that were not fairly well developed before 1912. With this great development-period reaching its zenith, large production began. The seeds of good-roads building that had been sown were growing and about the year 1908 the first definite steps toward mass or volume production were taken. Not until the Ford Motor Co. announced plans in the fall of that year for the production of 20,000 Model-T cars were the possibilities of reducing cost by virtue of mass production taken seriously into consideration. At about the same time the General Motors Corporation was organized, and a year later a necessary step was taken when the work of the Society of Automobile Engineers was actively begun.

From 1908 to 1920 we may follow the great production movement of the industry. Everyone in it could foresee that volume production would bring lower prices, but few if any had a real conception of the extent to which this would be carried. From 1912 until about 1920 large factories were being built, equipped with special modern machinery, and put on a production basis.

About the latter year a new era in production began in the industry. The great problem in the last 7 years has been to produce at a lower cost. This involved the redesigning of the parts to reduce the time of machine operations, the use of materials that machine faster and that cost less, and various kinds of research to further reduce the cost of the product. Thus the production era may be divided into two parts: (*a*) the first great effort toward mass production, with cost and selling price allowed to adjust themselves, because the demand from all parts of the Country was so great that manufacturers were unable to meet it; and (*b*) the second stage of production in which all companies are redesigning the parts so that they can be produced at a lower cost.

The Country's Leading Manufacturing Industry

Such, in brief, have been the development stages of the industry. Where does it stand with regard to other industries? According to the Bureau of the Census it is the leading industry of the Country. It stands first in value of production, and the statistics relate only to motor-cars and trucks. In 1926, for example, the manufacture of cars and trucks represented a total wholesale value of $3,163,000,000. This does not include tires nor the manufacture of accessories or any of the machinery that goes into the factories, garages and repair-shops.

The tire industry in itself is a $1,000,000,000 industry, and the parts and accessories industry a $750,000,000 one. If these were included, we should have virtually a $5,000,000,000 industry.

The automotive industry is related to and largely dependent upon other industries, and they are dependent upon it to a large extent. It takes 12½ per cent of the total iron and steel output, 53 per cent of the plate glass, 69 per cent of the leather products, 83 per cent of the rubber, 29 per cent of the aluminum, 12 per cent of the copper, 15 per cent of the tin, and 28 per cent of the nickel of the Country.

Viewed broadly, the industry is divided into two great branches which the student should keep in mind. The first is the manufacturing end and the second is the selling and maintenance division. This latter is greater than the manufacturing division; more money is spent yearly in operation and maintenance than in the purchase of new vehicles, and approximately as many persons are engaged in the industry outside the factories as inside. The factories employ 850,000, and it is somewhat of a coincidence that the same number is engaged in selling. The total of approximately 1,650,000 engaged in these two branches of the industry does not include the drivers of vehicles nor those engaged in operating fleets of motor-coaches and motor-trucks.

Selling and Maintenance Now in Lead

A tremendous organization has been spread over the Country to sell the 4,500,000 vehicles produced annually and to maintain the 22,000,000 vehicles that are in use. The selling requires about 50,000 dealer organizations, and college men are working up in many of these as sales managers and meeting great success.

About 83,000 shops are engaged in the repairing of the 22,000,000 vehicles. Nearly one-half of these are operated by motor-car dealers; the rest are independent repair-shops. Think of the great opportunities offered by these 83,000 places. We are faced with the problem of maintaining these vehicles in the best condition at the lowest possible cost, and there is a great demand throughout the Country today for young men with engineering training to head the service organizations. I know of one in New York City through which pass 18,000 repair-jobs a year; and in other cities some service organizations are becoming big industrial enterprises. They are being equipped with good machinery. Within the last 3 or 4 years our best builders of machine-tools have been turning attention to building precision machinery for these stations, and today the work in the service stations is of as great accuracy as that in the factories. Accessories are sold in 5000 automobile-supply stores throughout the Country, but accessories and supplies can be bought in 66,000 retail establishments.

Sales of new cars and trucks approximated $3,440,000,000 in 1926, but more than $4,000,000,000 was spent for maintenance and operation.

A great demand exists for operation and maintenance men. I know of operators of large fleets of trucks and motorcoaches who employ two or three engineers who are members of the Society. I know of young men who have started in the factories and have found excellent places for themselves in the operation and maintenance field. They are designing tools, putting maintenance and operation on an efficient basis, doing constructive work and making a much better livelihood than if they had remained in the factories.

Our great industrial and commercial corporations, the heads of which represent the best brains of the Country, are conducting transportation on the lowest cost-basis and have huge funds at their disposal. They are willing to go to any length necessary to reduce the cost of maintenance of the vehicles and put their operation on a higher standard. They are looking for the best engineering talent in the Country.

Highway Improvements Broadening the Industry

Some persons say that the saturation-point in automobile sales has arrived. We have heard such statements since 1912. There is no saturation-point, because the saturation-point in motor-vehicles is the saturation-point of transportation. That point seems to me to recede further and further as we look around and see the wonderful things that are happening. Think of the Federal road-system, of the building of 170,000 miles of highway to be completed in 1931; when that is completed, 90 per cent of the population of the Country will have that highway system directly at or within 10 miles of their doors. Who in these 112,000,000 can forego the use of an automobile? Think of the economic value of the car and this highway system.

Our Federal Government has appropriated $54,000,000 for the construction of this system, and our States are making appropriations that amount to as large a total. Wherever we look we see evidences of great improvements. Instead of narrowing, the industry is broadening. The vehicular tunnel under the Hudson River from New York City to New Jersey will be opened within a year, and the State of New Jersey is building a 13-mile roadway to extend from the mouth of the tunnel to a point south of Elizabeth. This tunnel and highway will shorten the time of every trip between New York City and Philadelphia by 1 hr. Consider what this will mean to commerce and the transportation of passengers.

In Chicago a new double-deck street has been built at a cost of $13,000,000. Think of the Bear Mountain Bridge over the Hudson River below West Point, and of the Bronx River Parkway. In every State in the Union great work on the highway system is being done. All of this means a broadening of the automotive industry and pushing the saturation-point further into the future.

In this connection another great factor in the industry to think about is traffic. The operator of a fleet of motor-vehicles has three problems: (*a*) operation, (*b*) maintenance, and (*c*) traffic. The traffic situation is very much in the public mind at present. Many of our cities have added traffic engineers to the executive department of the municipal government in the last 5 years, and within the next 3 or 4 years probably a score or more cities will be employing traffic engineers because these millions of vehicles must be kept moving.

OPPORTUNITIES IN DESIGN AND RESEARCH IN AUTOMOBILE ENGINEERING

BY J. H. HUNT[2]

DESIGN may be defined as including the application of known mechanisms and materials to obtain a specified result. Research involves study by analysis or experimentation to determine the capabilities of new materials, of new proportions in old mechanisms, usually made possible by new materials, or of new mechanisms.

Obviously, no automotive problem can be solved by using alone the methods either of design or of research. It is not possible to combine well-known mechanisms into new assemblies without raising questions for which the answer is unknown and that require research to obtain the answer. It is therefore very reasonable to consider the opportunities in the two lines of work together. No designer can be successful without ability to see where research is indicated and without a disposition to use research facilities to the most efficient extent. No research man can be useful in automotive work who does not realize fairly accurately the limitations under which the designer has to work, and who does not possess a disposition to arrange his own work so that it will be of direct

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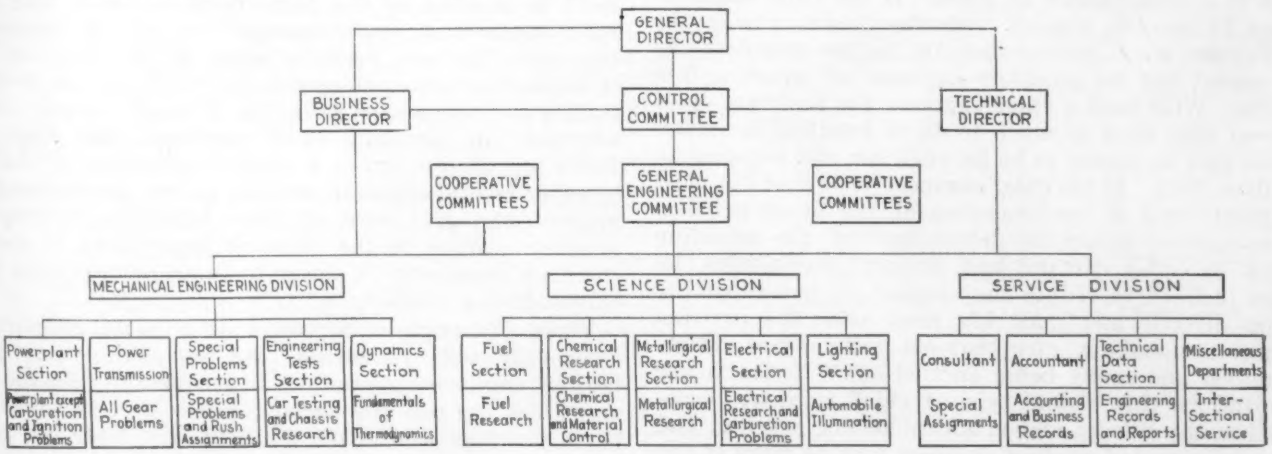

FIG. 1—HOW THE ENGINEERING DEPARTMENT OF A LARGE MOTOR-CAR MANUFACTURING COMPANY MIGHT BE ORGANIZED
The Vice-President in Charge of Engineering Works under and Reports to the General Manager. The Chief Engineer Is Directed by and Reports to the Vice-President in Charge of Engineering, If an Individual with Such a Title Is Embraced in the Organization; Otherwise He Comes Directly under the General Manager. Details of the Work Are Supervised by the Assistant Chief Engineer. These Higher Executives Have Access to One or More Outside Consulting Engineers Who May Be Paid Permanent Retainer Fees or Retained Temporarily for a Specific Purpose. Under the Assistant Chief Engineer the Staff Is Organized into Divisions or Groups That Handle Different Branches of the Work, Such as Chassis Engineering, Drafting, Body Engineering, Experimental Engineering, and Reseach. Each of These Divisions Has at Its Head an Engineer Who Is Directed by the Assistant Chief Engineer

assistance to the designer at the earliest possible moment.

The value of either the design or the research worker in a given organization is limited by his knowledge of the production methods of his own competing organization and of the possibilities of improvement in these methods. This knowledge of factory methods and conditions can best be acquired in the factory. The college-trained man who will take the time to gain this experience will have a real advantage over his competitors, particularly if he keeps his ultimate plan in mind.

In the early days of the industry a large part of the design and research ability of an organization was likely to be combined in the person of the chief engineer. He analyzed the problem presented, adopted old mechanisms to meet it or invented new ones, and decided what experimentation was necessary to prove the success of his design. Today, in all but the smaller companies, an extensive organization is maintained to perform this work. This condition is not only made possible by the size of the industry and its ability to support adequate engineering work, but is also necessary because of the narrow margin of profit, which makes it necessary to determine with certainty that the completed vehicle will give adequate public satisfaction without expensive service and thus build up production to the point where profits are assured.

Car-Factory Engineering-Department Organization

Today a typical organization will consist of a chief engineer; an assistant chief engineer or an executive engineer, depending on whether the chief engineer regards himself as a coordinating executive or as responsible primarily for engineering details; a staff of engineers such as chassis, body, experimental or research engineers; and an experimental-department superintendent in charge of the construction or testing of new designs. These men will be assisted and supported by a complete drafting-room organization whose work will include the keeping of proper records, and by metallurgical experts, experimental test men and mathematical analysts who are so located as to supply the greatest assistance to the men who must make the decisions.

Organizations in the automotive industry are built mainly around the men who happen to be available. While the organization chart in Fig. 1 might represent the set-up in a given company, I know of no company to which it applies exactly as given. If the chief engineer wishes to concern himself with the details during the development stage, he may have the engine specialist, the gear expert and the accessory engineer all report to him directly. With such a chief engineer the assistant chief engineer may have so much to do in handling executive routine that he ceases to be an engineer and becomes an executive clerk. If the chief engineer feels that his most important work is the analyzing of the broad problem of engineering policy as determined by the situation created by sales demand and factory possibilities, he will be inclined to reduce the number of men reporting to him directly and limit his work with the division engineers to making sure that his policies are clearly understood and really being carried out. In the larger organizations this second type of chief engineer sometimes has the title of vice-president of engineering, and the man designated as chief engineer may be more of the type that follows the detailed development.

Work of Research and Consulting Engineers

Research work has been defined in such a way as to include all experimental work. Some organizations will have a so-called experimental-engineer working on the problems of current production and will have another man working on problems relating to proposed or possible designs. In such an organization the experimental engineer might be studying the possibility of eliminating a cause of trouble on the road, such as the necessity of frequent valve-adjustment, while the research engineer might be working on the problem of reducing engine noises. Obviously, no essential difference in the nature of the work exists and the designation of the engineer to work on a given problem will depend as much on the pressure of other work as on the model of the car to which the results are to be applied.

Consulting engineers may have various functions in their connection with manufacturing companies. Frequently a consulting engineer of very broad experience, not only in engineering but in manufacturing and in business conditions, is retained by the general manager to advise him whether the general engineering policy of the company is correct and whether the program of work is planned in such a way as to reach the immediate objective in a reasonable time. Such an engineer would be consulted by anyone who was in a position to influence the engineering policy and would be paid a permanent-retainer fee. Another type of consulting engineer is a specialist who is called in to assist the company to meet an emergency when not enough time can be allowed for the regular staff to study the whole problem. Such an engineer might be selected and consulted by the chief engineer alone. Thus, a consulting engineer who really understood the "shimmy" problem would have been very busy following the advent of balloon tires.

It must not be inferred that the different engineers and their assistants really work according to the somewhat military line-up of the chart. Every individual whose position or function is shown is, in a sense, a sort of consulting engineer for anyone else in the whole group whose work is successful to the extent that such a situation exists. One of the first and most important problems of the young engineer is to learn how to render and how to obtain assistance in such a group, at the same time meeting all of his own responsibilities and without assuming any responsibilities that do not really belong to him.

Parts Companies Do Important Engineering Work

A great deal of important automotive engineering-work is handled by the parts manufacturers, who may have engineering staffs engaged not only in improving the parts they are manufacturing at the time but also in developing parts and accessories for future production. Such a staff, organized as in Fig. 2, might include a chief engineer; an assistant chief engineer, who may also follow up design work; a chief draftsman; a research or experimental engineer, and one or two development engineers who give most of their attention to proposed products. Work in the research department of such a company frequently is closer to fundamentals than in a car-producing company.

When the engineering work of a parts company is sufficiently well conducted, car companies that have limited engineering staffs will frequently delegate not only all of the real engineering on the part in which the parts company specializes but will rely upon the parts company for advice regarding other parts of the car. Thus, the engineers of a radiator company may find themselves concerned with problems that involve cylinder-head design, and the manufacturers of ignition equipment may find it necessary to have a well qualified carbureter man on their staff. Parts companies usually must have

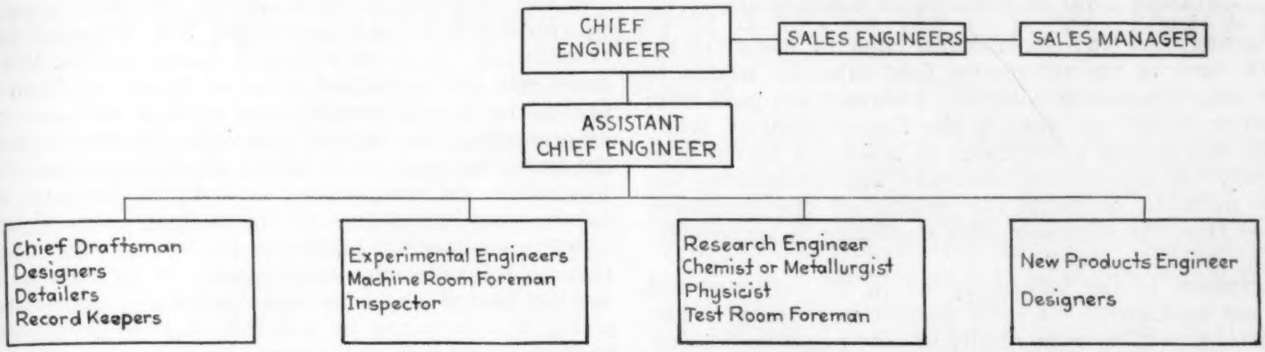

FIG. 2—POSSIBLE ORGANIZATION OF A LARGE PARTS COMPANY'S ENGINEERING DEPARTMENT
The Chief Engineer Has Close Contact With the Sales Engineers and Sales Manager and Directs His Assistant Chief Engineer, Who Has Immediate Supervision over the Heads of the Various Staff Divisions. The Chief Draftsman and His Subordinates Are Engaged on Work for Current Production, but as a Large Part of the Engineering Work in a Parts Company Is Devoted to the Development of New Devices, Other Groups Are Engaged Constantly in Experimental and Research Work and on Designs for Products To Be Brought Out in the Future. Many of the Small-Production Car Companies Depend upon the Parts Companies for Improvements in Individual Parts through These Classes of Work

sales engineers who, while not officially part of the engineering department proper, are, so far as their relation to the company's customers is concerned, really designing engineers.

Salaries in the parts companies are not likely to be quite so good as those paid by the more successful car companies because of the competitive situation which imposes pressure to keep down the overhead. On the other hand, salaries are likely to be better than for subordinate positions with the less active car manufacturers.

Research Engineering Growing in Importance

Recently some of the highly successful car companies have begun to realize the need of planning their engineering programs in such a way as to enable the companies to meet the probable demand for improvements for a period of years in advance. They have therefore created research organizations which are sufficiently well staffed to provide for attacking simultaneously the varied problems presented by all of the important component parts of a car. Such an organization can be extended almost indefinitely, since for each part, such as a transmission, we have not only the current problems of reducing weight and cost, together with securing smoother and quieter operation, but also the broad question of what the ideal transmission would be like and the possibility of producing one without the use of gears. This is particularly true since the gear man can soon become so engrossed in the details of immediate problems that, unless he is inclined to take a broad view of all the questions involved, he may become so much of a specialist that he will no longer be the best man to study the broad problem of the ideal transmission.

A possible organization set-up to handle the work of a large research organization is shown in Fig. 3. This shows openings for men with almost every kind of engineering and scientific training. Research problems are sufficiently detailed in scope that a comparatively inexperienced young engineer or scientist can do work of great value to the industry if his section head has a broad enough outlook to present to him with necessary accuracy the problem to be solved. But continued success of such an organization depends entirely on the understanding which these specialists have of the factory processes, organization, and design problems of the organization for which the work is being done.

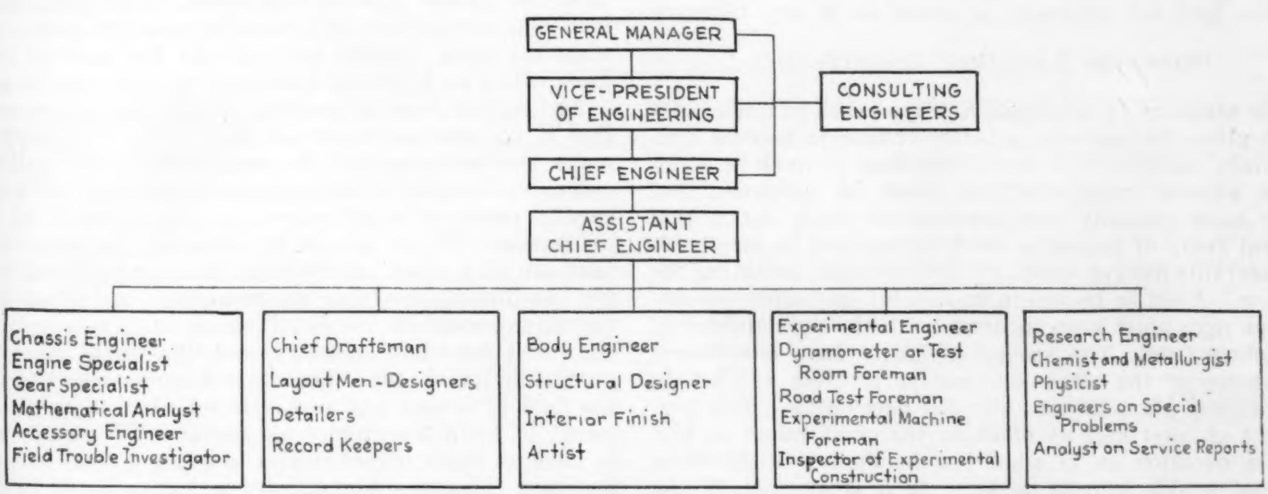

FIG. 3—POSSIBLE ORGANIZATION OF THE RESEARCH DIVISION OF A LARGE CAR-PRODUCTION COMPANY
This Is Entirely Distinct from the Engineering Department of the Company and Is Not Concerned with the Designing of Production Parts. It Deals with Special Problems That Arise in Connection with Components in Current Production, Such as the Powerplant and Transmission; Tests; and Research into Fuels and Their Best Utilization, Carburetion and Ignition, Lighting and the Like. The Service Division Keeps the Engineering Data and Business Records of the Organization and Performs Miscellaneous Functions. The Set-Up of the Organization Differs Radically from That of a Manufacturing Company's Engineering Department, as the Work Is Directed Largely by Committees in Cooperation with the General Director, Aided by a Business Director and a Technical Director. Such an Organization Affords Openings for Young Men with Almost Every Kind of Engineering Education

Salaries Paid in Engineering Branches

A young man who contemplates entering design or research work in the automotive field naturally wishes to know something about salaries. Detailers are paid from $1,800 to $2,000 per year in the Detroit district, while layout men receive about twice as much. A layout man is really an experienced designer and frequently has much more to do with the details of the completed vehicle than the engineer who nominally is responsible for it.

Beginners in the laboratory or in the experimental shop are paid about the same amount as detailers. The technical man of average ability usually progresses somewhat more rapidly in the laboratory than in the drafting-room at first, but may find himself handicapped later to some extent when competing for the position of division engineer with someone who has had experience in designing as well as drafting. Most of the chief engineers now in the industry have worked at the drawing-board, and it seems likely that this general situation will continue.

Salaries paid to research men who are part of the organization of a manufacturing company in which the engineering organization is expected primarily to produce designs are likely to be about the same as in other divisions, except when special reasons exist for assigning a certain man on a specific task.

Research laboratories which are not adjuncts of design-producing organizations are too new to have established any basis of salaries. It has been necessary to pay approximately what the usual engineering department would pay to secure the kind of men needed to get started. Whether salaries for the better man will advance as they might in a car company will be determined by the success of this type of research. Meanwhile, the individuals who are engaged in it have the fascination of working on most interesting problems.

Division engineers in a large organization receive from $5,000 a year to possibly twice as much, depending on the organization and the men. Chief engineers, and in particular those who are also company officers, are not only paid salaries that may be several times that of their assistants but often have some special bonus arrangement that can make them financially independent in a few years. Engineering salaries for leaders in the automotive field are probably as great as in any industry.

Beginners Have Good Opportunities

The tendency to subdivide and specialize in automotive work gives the beginner a better chance to become commercially valuable in a short time than in work in which more general responsibilities must be assumed; but since each specialty now involves so much detail that several years of intensive work is required to master it, considerable danger exists of the specialist becoming too narrow. Even to become a successful specialist the ambitious man must keep in touch with the development of the whole field. The specialist should have a sufficient knowledge of the whole automotive problem so that he can propose plans to his chief for developing a new possibility at least half as often as the chief comes to him with a question as to what can be done. Study alone will not enable him to do this, as a large part of the necessary information must come from colleagues who are working on other specialties.

In these days of aggressive sales promotion there seems to be a tendency to take from engineering into sales work young men of good personality who have the ability to talk convincingly about the merits of a product and the basis of its development. In most cases this provides a fortunate opportunity for the man who is transferred. It is to be hoped, however, that this tendency will not be carried so far as to sift out from engineering too large a proportion of the men who are capable of presenting the engineering case. Ability to present the main features of a technical situation in a convincing way will be an even greater asset to the engineer in the future than it has been in the past, because of the increasing tendency to settle the problems of an organization by balancing the requirements of all factors. The day has passed when any organization can succeed whose policy is determined by a series of snap judgments or by some rigid rule that cannot be changed to meet new conditions.

Future Promises a Satisfying Career

The question naturally arises whether as great a change in industry will occur in the next 20 years as in the last two decades. Prophesying is dangerous but every fact leads to the belief that the situation will not change greatly from the present unless some unexpected invention is brought forth or an unfortunate combination of circumstances greatly reduces our Country's prosperity. Even if petroleum supplies are exhausted, fuel from shale or other sources will be available at prices that will permit about the same utilization of motor-vehicles as at present but with greater tendency toward combining fuel economy. The whole social organization in this Country is so built around individual transportation that the automobile will continue to be indispensable, and the number of cars per family will increase. Nearly one-half of our annual production of 4,500,000 vehicles now goes to replace cars that are retired.

The competitive situation now compels everyone in the industry to bend every effort to find out the demands in each price class and then to give the most in service and comfort that is possible. Leaders in the industry must increase their engineering efforts if they are to retain their share of the business. This will mean larger engineering staffs and the giving of more attention to each detail. There will always be enough buyers who desire something different, even if they must pay an extra price for it, to enable the smaller companies to continue if they have the proper type of engineers. This situation will last long enough for each manufacturer to learn exactly what his public expects and will pay for, and for him to know when he is giving absolutely all that can be given.

No one can predict how long it will take to accomplish this if no new materials are developed. We know that many new materials will become available that will make extensive changes in design possible and that will require careful research to determine the best methods of their utilization. So far as can be foreseen, the only change that can slow down engineering in a fundamental industry like that of providing the means for individual transportation would be the development of a monopoly that embraced the whole industry, and this would seem to be absolutely impossible. Therefore a young man can enter the field of design and research with the expectation of plenty of work throughout his career. He cannot expect to have as many opportunities to enter a small company and have this carry him upward as has occurred in many cases in the past; he must also expect keener competition than the last generation met. We have every reason to believe that the prizes will be as great as in the past, both the financial rewards and the satisfaction that comes with having work in the technical phases that is worthwhile.

FIELD FOR THE MOTOR-TRANSPORT ENGINEER

BY R. E. PLIMPTON[3]

THE field of utilization of motor-vehicles by the operators of fleets has been said by a Past-President of the Society, C. M. Manly, to offer more opportunities in the future than all other branches of the industry together. I do not think I can state the importance of this field more emphatically than this statement by one who has studied the broad field of automotive engineering for years.

The first consideration of large-scale motor-vehicle operation came from the manufacturers, who were forced to assume certain repair functions for the millions of individuals to whom their product was sold; therefore many engineers are engaged in the service departments of the motor-car companies and dealers. These service departments have not attained to 100-per cent operating or user status, but they offer worthwhile openings and also provide training for many positions with fleet operators or transportation companies.

Service work has certain peculiarities, especially when it is performed by a manufacturer's or dealer's organization. The prime object of the manufacturer or dealer is to sell vehicles, and the service work must be subordinate to this. But in the last year or two the service work has increased in importance and we are beginning to hear of vice-presidents of service, which is a title that formerly was absolutely unknown. Now the man who is in charge of service often reports directly to the general manager and is a much more important man than the service manager ever was before. Those who are engaged in work in such service departments have no opportunity to perform routine or preventive maintenance. They never can do more than a limited part of real maintenance work; nevertheless, a great deal of real engineering activity has been carried on in this field.

The adoption in all parts of the Country of the flat-rate system of payment for labor and of charging for work done is an example of the application of production engineering of a high type to the service branch of the industry. At some vehicle factories men under the service manager have given the subject thorough study, and it is as much creative work as any work that is done in the designing of the vehicle.

The World War developed the large-scale use of motor-vehicles, hence the demand for trained engineers. Many of the men who developed from mechanics into superintendents and supervisors are as truly engineers as those who have studied engineering in colleges, but today preference is given to young men who have had institutional engineering education.

Work of a Maintenance Organization

Motor transport became really organized during the war, both in the fighting areas and in this Country which was confronted with a great shortage of railroad transportation. As a result of this war-time experience and the specialization it indicated as possible in the technique of maintenance and operation, two forms of motor transport or fleet installation have emerged and developed. In the first, the main engineering problem, and therefore the main opening for young engineers, is in connection with the maintenance of automotive equipment. Operation usually is in other hands, because the use of the vehicles forms part of broader business; thus, the units of a fleet operated by a public utility may be used in construction and repair work, by salesmen and in other ways; hence the drivers are not responsible to the man who has charge of the maintenance of equipment.

Large organizations have grown up in the field of motor-transport maintenance. Regarding the functions of the chief executive in such an organization, J. F. Winchester says, "The man in charge must know all the

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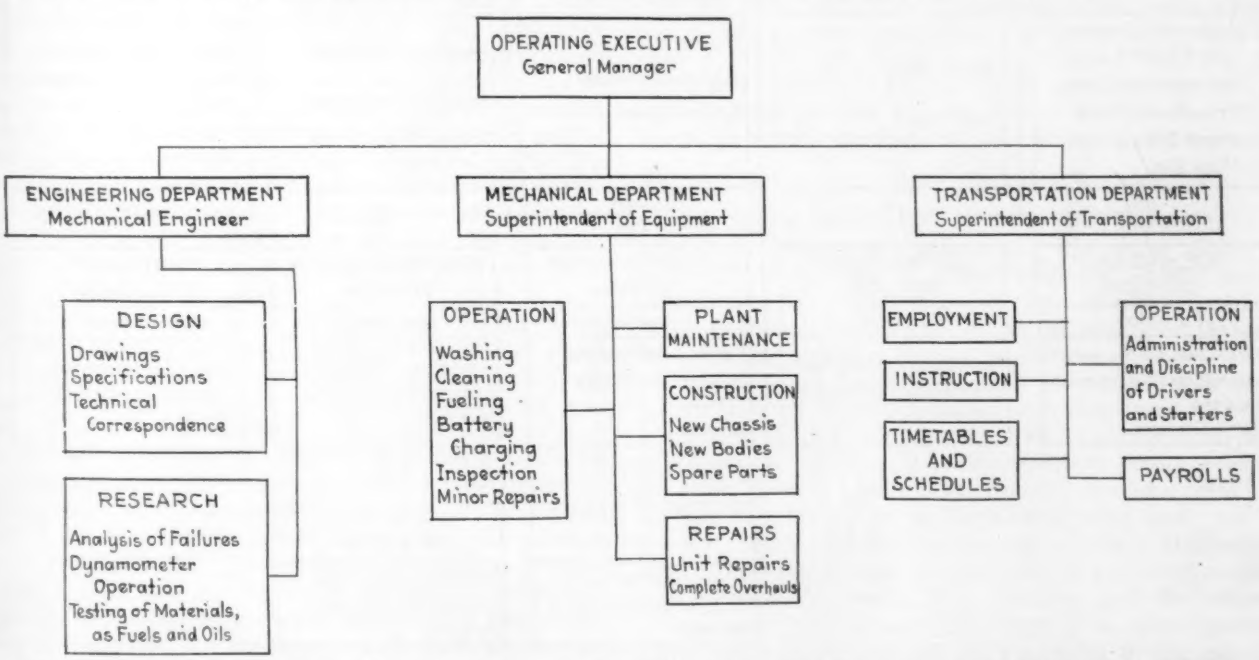

FIG. 4—TYPICAL FUNCTIONS OF A LARGE ORGANIZATION OPERATING AUTOMOTIVE EQUIPMENT IN CITY PASSENGER-SERVICE
Designation of a Particular Kind of Work or Function Suggests the Personnel To Perform It. Besides the Departments Shown in the Chart, Large Transportation Companies Have Other Departments Specializing in Legal Matters and Accounting, and May Have Plant Facilities and Personnel in a Number of Outlying Communities. The Organization Shown in the Chart Gives More than Usual Attention for an Operating Company to Design and Construction

factors that go with the manufacturing phase of the industry." That is, he must have a knowledge of design, research, and production, and be an all-round man. Mr. Winchester says further:

> The job also calls for an understanding of general industrial problems from an employment and labor-handling standpoint; for an understanding of general research in all problems relating to the industry, so that the executive can determine whether there is any practical and economical possibility of adopting the latest devices; and calls for a broad knowledge of general financial-conditions which can be used to advantage in the purchase of equipment requirements.

Shops in which modern fleets of motor-vehicles are maintained follow the practice of many production shops. They have a large stockroom in which reserve parts are kept; testing equipment, such as dynamometers and test stands for small generators or starters; battery departments; grinders for refinishing cylinder-blocks; welding apparatus, and upholstery, woodworking, and other equipment.

Public Transportation Field Offers Good Future

The second form of large-scale installation consists of fleets of motor-vehicles operated by companies that derive their revenue solely from transportation. This field seems to me to offer one of the most attractive of futures for the young engineer. Apart from the maintenance of equipment, the engineers in this kind of an organization may have such work as the control of drivers, the direction of passenger and freight transportation, supervision of public relations, and the like. Probably it will be of interest to learn some of the opportunities in this field. The following letter was received from the vice-president of a company that operates about 50 vehicles in city passenger-service:

> In our garage we can use a young mechanical engineer who is willing to put on overalls and work with his hands and has analyzing and planning ability. Some night work will be required, at least in the beginning. The question of salary is open, although we will not pay much over $175 a month. If you know of any man suitable for the position, we would appreciate it if you would have him communicate with us.

This shows the definite opportunity in these fleet installations to start practically as a mechanic and, through the ability to plan and organize work, to advance through the ranks to a position as foreman and, finally, to become an executive. It will be hard work, however, and will not attract a man unless he has a keen realization of the future of this transportation industry. Openings also occur in the operating end. Many general managers in the passenger-transportation field believe that their operating executives should come up through the drivers' ranks; only by starting as a driver, they think, can a man gain the necessary knowledge of the public and the technique of dealing with passengers. From a job as

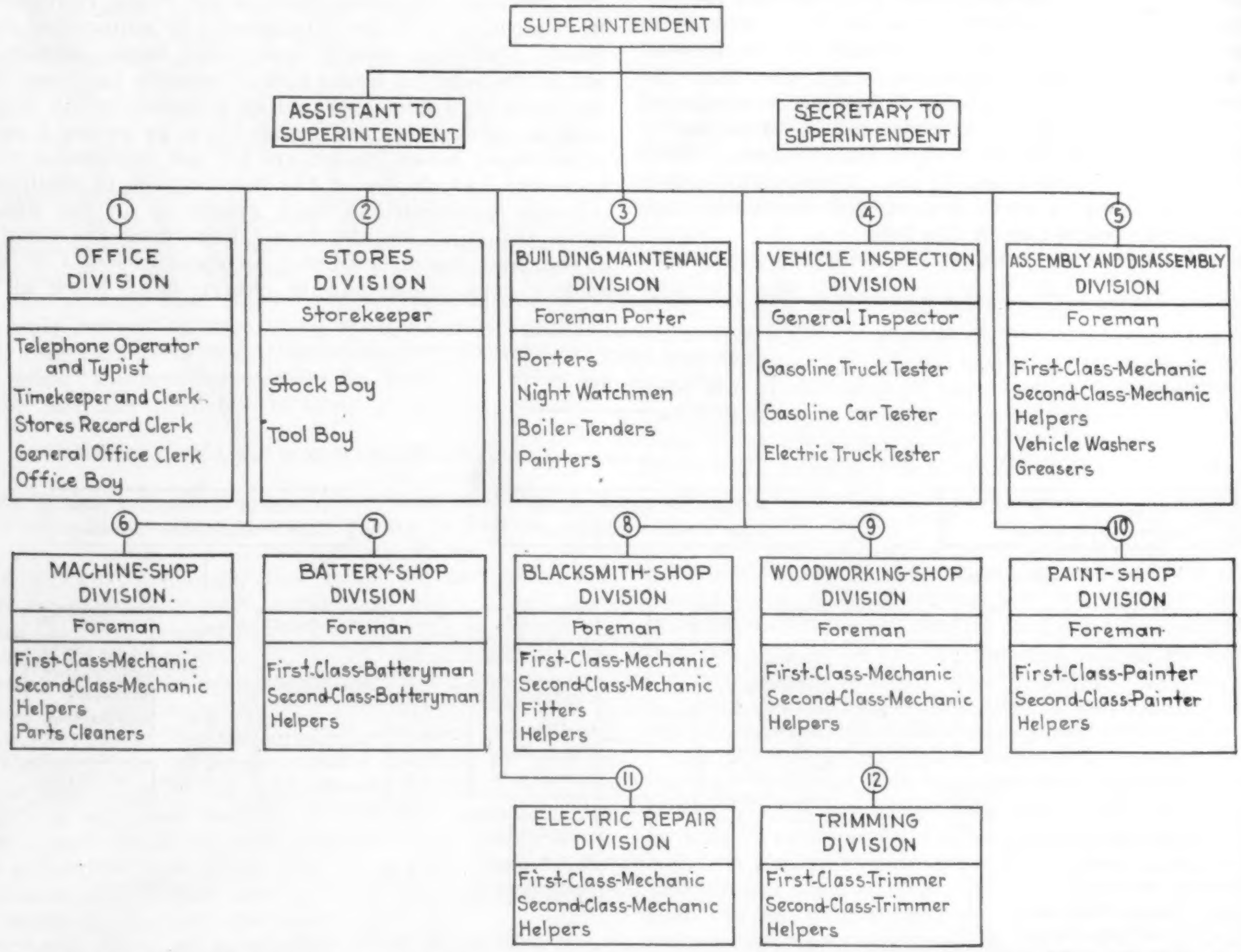

Fig. 5—Personnel Organization of Transportation Department of a Public Utility Operating Motor-Trucks and Automobiles

The Organization Shown Is Equipped with Facilities and Men for Production of Vehicles and Parts as Well as for Maintenance. Automotive Transportation Is an Adjunct to Other Departmental Functions, and the Use on Operation of Vehicles Is Controlled Largely by these Other Departments

driver, a man may be advanced to the position of starter or supervisor, and then the supervision of a district.

Good openings occur also in the traffic department, which is really the sales department of a transportation organization. It deals with the public, tries to build up business, and often has such planning work as the study of schedules. A young man may be wanted who can go out over a given route or a length of highway and call on the residents along it to learn their attitude toward the company and whether they use its service, and thus help to create good-will and induce more of them to ride in the vehicles.

Operating and Maintenance Organizations

These openings are illustrated in the two charts, Figs. 4 and 5, which relate to a transportation organization and a maintenance organization, respectively. Fig. 4 deals with functions and Fig. 5 with personnel, although the two are closely related and mention of a particular kind of work, or function, suggests the personnel to perform it, and vice-versa.

In addition to the departments shown in Fig. 4, a large transportation company has specialists for handling legal matters, claims arising from accidents, and accounting for revenues and operating expenses. If the company does business over a wide territory, as is frequently the case, the organization is decentralized as regards both operation and maintenance. At some central location will be grouped executives and plant facilities for the two branches of the business. Important outlying communities will have division superintendents, with supervisors and starters to control the drivers, and with garage foremen and mechanical assistants to care for light repairs and routine inspection. The heavy repairs for all equipment will be handled in shops at the headquarters, where the general supervision of operation is also centered.

A peculiarity of the organization charted in Fig. 4 is the attention paid to design and construction. Instead of purchasing complete vehicles, the necessary parts and materials are procured and assembled, on the basis of the transportation company's operating experience. Even when standard automotive equipment is used, the larger organizations are to a considerable extent manufacturing concerns, engaged in construction to meet their distinctive requirements and those needed on account of accidents or obsolescence.

The activities of an organization geared up to handle such manufacturing, as well as routine maintenance, are charted in Fig. 5. This is for a large public utility in which automotive transportation is merely an adjunct to other departmental functions. The use or operation of the vehicles is controlled largely by the other divisions, and the transportation department, so-called, is really devoted to maintenance of the equipment. The maintenance organization includes 12 divisions, as shown, all of which are aided to a great extent by extensive labor-saving facilities.

These two charts and the preceding discussion indicate the importance of the organizations that are developing to operate and maintain motor-transport installations. To man them efficiently, a trained personnel is essential. The young engineer, if he is willing to work up through the ranks, should prove ideal material. If he has the vision to look ahead to what will become one of the most important of all the transportation industries, the field of motor-transport operation and maintenance offers the young man with the "willingness to serve" a future that is comparable with that of the better-known fields, such as research, design, production and sales engineering.

HOW TO BECOME AN EXECUTIVE

BY JOHN YOUNGER[1]

MANY think that the big step in a man's life is taken when he leaves high school and goes to a university. True, this is the beginning of the period when he is looked upon as a man with ability to control his own affairs; but it is merely the continuation of schooling. The great majority of men in this period are still under some parental financial control. The big step comes when the young man is faced with the necessity of leaving the academic atmosphere and starting to make his own way and his own money. He can look forward to about 50 years of business activity; what shall he do in these 50 years?

Until recent years the work of most men in this period was concentrated on the product; the education given in universities reflected this. Men were educated, and, incidentally, still are educated, in the importance of materials, stresses and design. The important object formerly was to produce a product that would function. When James Watt built his steam-engine he did not think of the cost nor of the economics of operation; he merely thought, I assume, that here was an engineering product that actually worked. This attitude of mind continued until the recent rise of the mass-production industries took all the emphasis away from the product and placed it fairly and squarely on the process and, more particularly, on the cost of the process.

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What does this change mean to young men who are ambitious to take their place in the world? It means that a knowledge of materials, stresses and design is no longer sufficient; that it must be supplemented with a knowledge of the process. And this leads into the study of human engineering and of costs and economics.

Education Must Include Economics

The young man must broaden his education if he wishes to become an executive. He must study cost accounting, economics, work analysis, work routing, standardization, simplification and waste elimination, labor problems and, above all, must give more attention to workshop courses than ever before.

It should not be thought that because this is said to be an age of specialization the young man can learn his life work in a comparatively short time. If he wants to become a foreman, a superintendent, or an executive, he must have a broad background. An executive today is like the leader of an orchestra, who does not play an instrument himself but has an intimate knowledge of every instrument and its capabilities and very definitely understands the music it is playing and its tempo.

Similarly, the general manager of a large industrial plant must coordinate all the functions of the plant and weld them into a smoothly working machine. One of his greatest problems is to handle men. Men work because of various motives. Some, like scientists and ar-

tisans, work because of interest in the work itself; some, like business men and financiers, work for love of money; some, like teachers, clergymen, and army men, work for the love of service; and some, like the tramp, do not work at all. This human element is all-important and must be understood.

The general manager is constantly asking, "What will it cost?" The making and saving of money is a prime object in an industrial plant today. Managers are chosen for their ability to make profits continuously and consistently. Sometimes the manager works alone and sometimes he has a staff to help him. Some persons will say that the executive's desk has a drawer filled with golf balls on one side and another full of cigars on the other side and that the top has nothing on it. That situation was partially true during the war, when orders came in of themselves, but today, when the manufacturer must go out and capture orders by virtue of low price against severe competition, the general manager is one of the busiest men in the plant.

How Imagination Should Be Used

Let us consider the position in which the young man will find himself in a few months or a year or two. He is in a big plant filled with a multitude of machines. His educational life is behind him and his job is before him. It is then that he begins to realize that education is only the beginning of life; it is only the foundation on which he is to build. He feels that there is a vast amount to learn, but hopes he can learn it faster than the man above him can find out how little he knows about the work.

Suppose the first task he is given is the turning of a common 5/8 x 2-in. bolt. He may think that this is insignificant, but let him use imagination; think where the bolt came from, back to the rod mill, the blooming mill, the open-hearth furnace and to the ore mine. The purchasing agent who ordered the steel from which the bolt is made satisfied himself regarding the source of the steel and its quality. The beginner should project his thoughts into the mind of the purchasing agent, for some day he will be in a position where he will need to know something about the work of the purchasing agent.

Conversely, he should let his thoughts run forward to what the bolt is to be used for. Perhaps it is one of many that will hold a cylinder-head to a cylinder-block, in which case the young worker should study for himself the pressures and stresses in the cylinder-block and the stresses in the bolt he is making. By ascertaining the area of the cross-section and the strength of the metal, he can determine the factor of safety allowed by the engineer. Thus he will be projecting himself into the engineer's place and some day may be directing the engineer.

Let him study the men around him and try to find out, diplomatically of course, why they are hired, how they are selected, trained, promoted, and even how they are discharged. The strength of an enterprise is measured by its man-power. Henry Ford, in his book Today and Tomorrow, states that it was not his huge plant nor his equipment that gave him success, but his men.

Promotion Comes to the Prepared Man

Once when I was visiting the mammoth Ford plant at Highland Park, Mich., I was impressed by the great number of machine-tools, but my guide gave me a lesson in observation. He told me to regard the machines individually and to realize that all the machines in a particular department were simply one machine multiplied by n. When visiting other plants subsequently this enabled me to disentangle the important key-machines for the process from the multitude that surrounded me.

One should not dismiss this suggestion of after-study in industry with the thought that study is over when the university is left behind. Real study is just beginning for the man who wants to become a general manager. This is not a theoretical idea I am offering; in my own apprenticeship days a group of co-workers formed a small society and studied our work as I have outlined, and each of us was ready for promotion when it came.

The 10 P's of work are:

(1) Policy
(2) Product
(3) Process
(4) Production
(5) Planning
(6) Personnel
(7) 'Prenticeship
(8) Purchasing
(9) Patronage
(10) Profits

If each of these items is studied, the ambitious young worker will learn as much about the business as the general manager knows and will qualify himself for the larger field that some day will open to him. This is the big thought in work: Promotion comes to the man who is ready for it.

LINCOLN ARC-WELDING PRIZES

To encourage improvements in the art of arc welding, the Lincoln Electric Co. has donated $17,500 to be awarded by the American Society of Mechanical Engineers for the best three papers disclosing advance in the art submitted in a worldwide competition. Prizes of $10,000, $5,000 and $2,500 will be presented at the 1928 Spring Meeting of the American Society of Mechanical Engineers, providing the papers that are submitted in the competition are of sufficient importance and value, in the opinion of the judges, to justify the awarding of the prizes.

To be considered in this competition, all papers must bear evidence of having been sent before Jan. 1, 1928. Any paper arriving after Jan. 31, 1928, will be disqualified. Members wishing to secure further information regarding the competition should address the American Society of Mechanical Engineers, 29 West 39th Street, New York City.

Vol. XX May, 1927 No. 5

Methods of Measuring the Antiknock Value of Fuels[1]

By H. K. Cummings[2]

Annual Meeting Paper *Illustrated with* Charts, Drawings and Photographs

ABSTRACT

THIS paper was prepared as part of the Cooperative Fuel Research program and presents mainly a review of published data on methods of measuring the anti-detonating qualities of motor fuels. Although detonation as a factor in gaseous explosive reactions is not a new subject, the general recognition of antiknock value as an important quality of automotive engine-fuels is comparatively recent. Reference is made to bibliographies covering earlier work in this field, and an outline is given of work now in progress at various laboratories and universities.

Ricardo's two test-engines and his methods of rating fuels in terms of highest useful compression-ratio and toluene value are described, and the applicability of his results to other engines is discussed. The British Air Ministry Laboratory, using a Ricardo variable-compression engine, compares fuels on the basis of percentage of increase in highest useful compression-ratio.

The method developed in the General Motors Corporation Research Laboratories employs the Midgley bouncing-pin indicator and a Delco engine to rate fuels in terms of a system of reference fuels. This same indicator is used by the Sun Oil Co. to compare the knock intensity of different fuels under like operating-conditions in a given engine, the precautions necessary to assure such conditions being enumerated.

Work at Ohio State University is centered on the value of various knock-suppressers, a proposed method of estimating detonation intensity by measuring gaseous ionization during combustion being described.

At Armour Institute, fuels are tested in an automobile engine and rated in terms of the degrees of spark-advance required to produce certain specified knock-intensities.

A bomb method used at the University of Michigan bases fuel ratings on the quantity of nitrogen that must be added to each gasoline-oxygen mixture to eliminate detonation. Peaks on the pressure-time curves, obtained with an optical indicator, are taken as evidence of detonation. The Delco engine and Midgley bouncing-pin indicator are also used to obtain benzol equivalents of blended gasolines.

The Kansas City Testing-Laboratory, using a single-cylinder stationary engine, rates fuels by two methods, namely, (*a*) comparing the maximum brake horsepower, and (*b*) finding the benzol equivalents.

Egloff and Morrell, proposing to compute the aromatic equivalents of gasolines from chemical analyses and from Ricardo's data on the toluene value of pure hydrocarbons, verified the results by comparing them with those obtained from benzol-gasoline blends in an automobile engine, the criterion being the spark-advance giving a definite knock-intensity.

Investigators at the University of Iowa, using a two-cylinder motorcycle engine, rate fuels in terms of the brake mean effective pressure at which knocking begins under identical operating-conditions.

The methods in use at the Bureau of Standards are described, with particular reference to the routine engine-test devised in 1924. In this test, a single-cylinder high-compression engine is used, the throttle being opened for each fuel until a certain minimum intensity of detonation is present. Fuels are compared with a reference fuel under like operating-conditions, the antiknock value being expressed as the percentage of increase in maximum permissible horsepower. Data are presented with regard to a detonation bomb being developed for the Bureau of Aeronautics. This bomb has a diaphragm in the head. A steel ball placed on this diaphragm is thrown upward when detonation occurs, the square root of the height of travel being taken as an indication of the detonation intensity.

The conclusions reached are that (*a*) nearly all the methods in use consist of engine tests or depend on engine tests for their interpretation; (*b*) knock intensity is measured in various ways and with differing degrees of definiteness; (*c*) the antiknock value of a fuel may be expressed in a variety of terms according to the particular method of test; and (*d*) the rating of fuels by existing methods is usually not independent of test conditions.

LAST April, the Steering Committee of the Cooperative Fuel Research requested the Bureau of Standards to make a survey of current methods of measuring the anti-detonating qualities of motor fuels. This paper presents the results of such survey. In general, only published methods are considered, as time was not available to make a more extended investigation. If there are methods in use differing essentially from those herein described, the discussion will afford an opportunity for bringing them to the attention of the Society.

The action of the Bureau of Standards and the National Research Council in supplying a 20-per cent benzol-blend to our flying-fields in 1917 is noteworthy as marking the first official recognition, at least in this Country, of the value of antiknock fuels. Detonation as a factor in gaseous explosive reactions received attention, however, at least half a century ago. We cannot undertake here to go into the work of LeChatelier, Berthelot, Jouget, Dixon, Petavel and the others, but it may be worth while to invite attention to a few excellent bibliographies in this field. Berl and Fischer in an article[3] on Researches on Explosive Gas and Vapor-Air Mixtures give 90 references and these are supplemented by Clark and Thee in their paper[4] on the Present Status of the Facts and Theories of Detonation with a list of 60 additional references. Bulletin No. 133 of the University of Illinois Engineering Experiment Sta-

[1] Published by permission of the Director of the Bureau of Standards, City of Washington.

[2] Associate physicist, automotive powerplants section, Bureau of Standards, City of Washington.

[3] See *Zeitschrift für Elektrochemie*, January, 1924, p. 29.

[4] See *Industrial and Engineering Chemistry*, December, 1925, p. 1226.

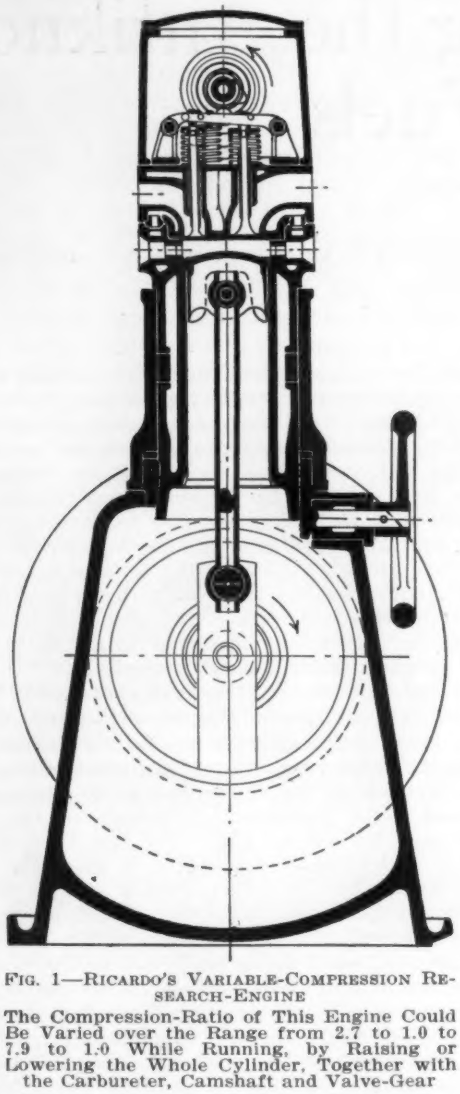


FIG. 1—RICARDO'S VARIABLE-COMPRESSION RESEARCH-ENGINE
The Compression-Ratio of This Engine Could Be Varied over the Range from 2.7 to 1.0 to 7.9 to 1.0 While Running, by Raising or Lowering the Whole Cylinder, Together with the Carbureter, Camshaft and Valve-Gear

tion, A Study of Explosions of Gaseous Mixtures, contains a bibliography of 217 titles and Bulletin No. 157 of the same series, An Investigation of the Mechanism of Explosive Reactions, adds 157 references. Some of this material may be of particular value to those who are trying to find a substitute for the engine test as a criterion of antiknock value.

ASIATIC PETROLEUM CO.

Ricardo's work on detonation[5] was done mainly from 1919 to 1921 for the Asiatic Petroleum Co., which provided as a reference fuel about 5 tons of light gasoline containing less than 2 per cent of aromatic hydrocarbons and about 63 per cent of paraffin hydrocarbons. He employed two special research-engines: (*a*) a variable-compression engine, Fig. 1, the compression-ratio of which could be varied over the range from 2.70 to 1.00 to 7.90 to 1.00 while running, by raising or lowering the whole cylinder, together with the carbureter, camshaft and valve-gear; and (*b*) a supercharging engine, Fig. 2, having a compression-ratio of 5.18 to 1.00, and fitted with a crosshead-type piston, which compresses air in a chamber below the piston during the suction and expansion strokes. This compressed air is admitted to the cylinder through ports that are just uncovered by the piston at the bottom of its stroke. The cylinder is thus alternately supercharged and scavenged. Tests were made with each engine at constant speed and under constant-temperature conditions on commercial gasoline and on pure substances.

As particular advantages of the supercharging engine, Ricardo claimed that the excess air assured complete combustion over a wide range of mixture-ratios and pointed out that the power developed was determined by the compression-pressure, which could be increased from 116 to 155 lb. per sq. in. The detonation-point for each fuel in this engine was taken to be the indicated mean effective pressure at which detonation became audible. With the variable-compression engine, mixture-ratio runs were required to ascertain the optimum carbureter-setting for each compression-ratio. The detonation-point for each fuel in this engine was taken to be the compression-ratio at which detonation first became audible under certain definite temperature conditions with optimum spark-advance and mixture-strength and was designated as the highest useful compression-ratio for the fuel. The fuels were also rated in terms of toluene values. Toluene value was defined as meaning the percentage of toluene that must be blended with Ricardo's "aromatic free" reference-fuel to equal the performance of a given fuel as regards de-

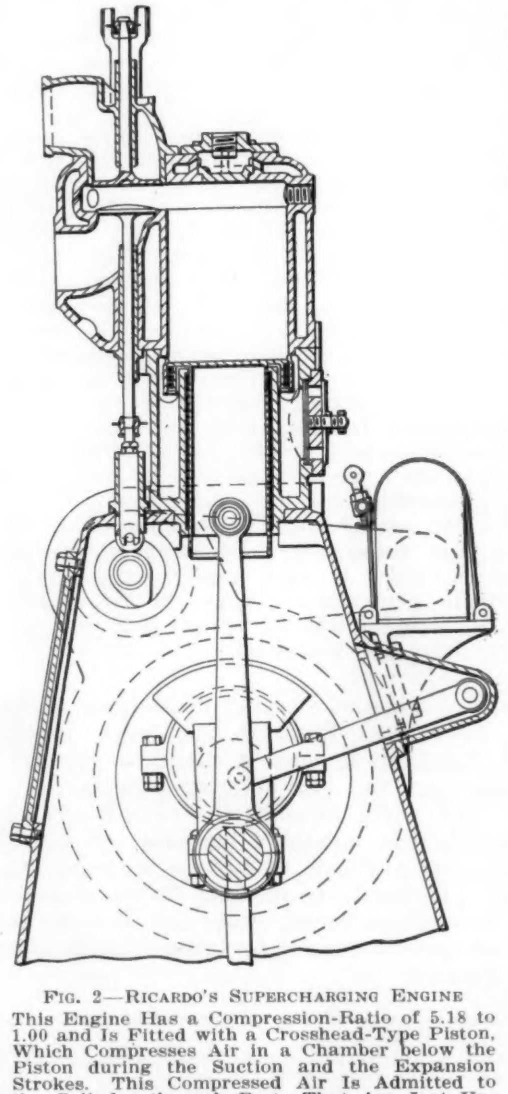


FIG. 2—RICARDO'S SUPERCHARGING ENGINE
This Engine Has a Compression-Ratio of 5.18 to 1.00 and Is Fitted with a Crosshead-Type Piston, Which Compresses Air in a Chamber below the Piston during the Suction and the Expansion Strokes. This Compressed Air Is Admitted to the Cylinder through Ports That Are Just Uncovered at the Bottom of Its Stroke. The Cylinder Is Thus Alternately Supercharged and Scavenged

[5] See Empire Motor Fuels Committee Report, section 2; also *The Automobile Engineer*, February, 1921, p. 51; March, 1921, p. 92; and April, 1921, p. 130; and *Automotive Industries*, April 14, p. 804; April 21, p. 856; and May 12, 1921, p. 1003.

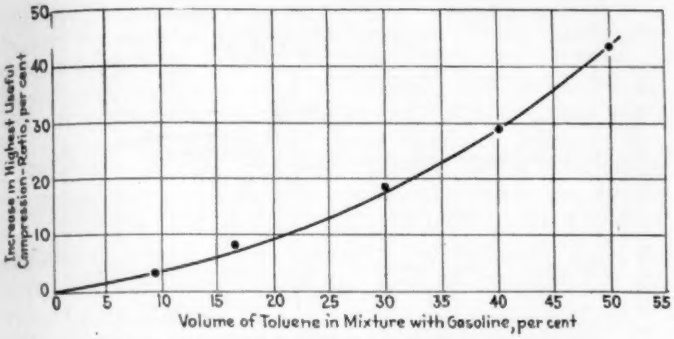


FIG. 3—ANTIKNOCK VALUE OF BLENDED FUELS
This Curve Is Taken From the Report of the British Air-Ministry Laboratory and Shows the Increase in Percentage of the Highest Useful Compression-Ratio as the Percentage by Volume Of Toluene Is Increased

tonation. Thus, by definition, the reference fuel had zero toluene value, and toluene itself had a value of 100. The toluene values obtained for a given fuel with the two engines were in general agreement but were not identical. The greatest divergence was found in the case of Fuels *B* and *H* for which the variable-compression engine gave values of 28 and 35, respectively, while the supercharging engine gave 18 and 24. As the reference fuel contained about 35 per cent of naphthenes, it was necessary to assign negative toluene values to the pure paraffin hydrocarbons. Thus, heptane was given a toluene value of —37.

Ricardo found that his results could not be applied directly to commercial engines on account of the marked influence of engine design on the tendency to detonate. Thus, one truck-engine having a compression-ratio of 3.95 to 1.00 detonated alarmingly on a fuel having a toluene value of +10 per cent, while the variable-compression engine showed no tendency to detonate on this fuel below a compression-ratio of 5 to 1. He estimated, in 1921, that the majority of automobile engines then in use required a fuel of toluene value between 15 and 20. Further points that should be kept in mind in applying Ricardo's results are the facts that (*a*) in neither of his engines was he able to induce detonation under any circumstances with ethyl alcohol, acetone, toluene or xylene, and (*b*) in the variable-compression engine preignition rather than detonation determined the highest useful compression-ratio with benzene, cyclohexane, wood alcohol and certain other fuels. This seems to be a consequence of engine design, since the Bureau of Standards single-cylinder test-engine gave satisfactory performance with motor benzol and with ethyl alcohol at compression-ratios of 11.5 to 1.0 and 14.0 to 1.0.

BRITISH AIR MINISTRY LABORATORY

Two reports[6] from the British Air Ministry Laboratory that appeared in 1926 describe engine tests on gasolines, blends and doped fuels by King and Sims and by Sims and Mardles. A Ricardo variable-compression engine of the type already described was employed under the following fixed operating-conditions: full throttle at 1500 r.p.m., 30-deg. spark-advance, two spark-plugs diametrically opposite, cooling-water outlet-temperature at 60 deg. cent. (140 deg. fahr.), and heat input to the carbureter, 1500 watts. The mixture-ratio was adjusted for the optimum but the spark-advance was kept constant. No indicator for measuring the intensity of detonation was found necessary. The experimenters state their procedure as follows:

> Observations were started in every case with the movable cylinder-head set for a low value of the compression-ratio and conditions were allowed to reach a steady state. The cylinder-head was then moved down to increase the compression-ratio until the first slight regular pinking occurred, and then further until pinking became more pronounced at intervals. The value of the compression-ratio reached at this second stage of the onset of detonation has been taken as representing the highest useful compression-ratio.

This resulted in slightly higher values of the highest useful compression-ratio with any particular fuel than were found by Ricardo with the same engine, but the results on comparing the fuels seem to be substantially the same. The degree of detonation here taken as standard was such that switching to a non-detonating fuel gave an increase in scale reading of about 0.3 lb. Engine power continued to increase with increase of compression-ratio beyond the highest useful compression-ratio but at a lower rate than would obtain with no detonation. These observers experienced more trouble than Ricardo with the preignition at the higher compression-ratios, and eventually the bronze of the cylinder-head failed between the exhaust-valves, revealing a malformation of the cooling-water passages in the head sufficient to account for considerable overheating. The results are usually given in terms of percentage of increase in highest useful compression-ratio as in Fig. 3. Colloidal solutions in gasoline of the metals, lead, nickel and iron, were found to increase the highest useful compression-ratio about the same amount as did the addition of equivalent concentrations of tetraethyl lead, nickel carbonyl and iron carbonyl. Table 1 shows data reported by Sims and Mardles.

GENERAL MOTORS CORPORATION RESEARCH LABORATORIES

Five years ago, Midgley and Boyd[7] discussed methods of measuring detonation in engines before this Society and presented a new method for measuring the intensity of detonation. Today, the Midgley bouncing-pin apparatus is more generally used for this purpose than any other single device. The bouncing-pin is a slender steel-rod, the lower end of which rests on the piston of a modified optical-indicator pressure-element. The original pressure-element is shown in the upper left-hand corner of Fig. 4. The modification consists in removing the oscillating mirror and the mechanism connecting it with the piston. The piston is restrained by so stiff a spring that its motion is very slight under normal pressure-changes in the cylinder. When detonation occurs, the bouncing-pin is thrown free of the piston and its upper end strikes a pair of spring contacts, closing an electrical circuit. This circuit contains a 100-watt lamp and a water voltameter in series with a source of 110-volt direct-current. Whenever the circuit is closed, water is

TABLE 1—RELATIVE EFFICACY OF PYROPHORIC METALS, USING EQUAL WEIGHTS

Fuel	Metal Per Liter, Grams	Dope Per Gallon, Grams	Highest Useful Compression-Ratio	Increase of Highest Useful Compression-Ratio, Per Cent
Gasoline	0	0	4.60	0
Gasoline + Tetraethyl Lead	2.0	12.1	6.45	40
Gasoline + Nickel Carbonyl	2.0	22.0	6.80	48
Gasoline + Iron Carbonyl	2.0	27.3	7.41	61

[6] See Aeronautical Research Committee Reports and Memoranda, No. 1013 and No. 1021; also *Engineering* (London) April 30, 1926, p. 575; and *Transactions of the Faraday Society*, October, 1926, p. 363.

[7] See THE JOURNAL, January, 1922, p. 7, and June, 1922, p. 451; and *Industrial and Engineering Chemistry*, July, 1922, p. 589 and October, 1922, p. 894.

decomposed and gas is produced, which collects in the graduated arm of the U-tube. The volume of gas collected in a given interval of time depends on the number and the intensity of the impulses given to the bouncing-pin during that time.

For testing purposes, Midgley and Boyd used a small Delco lighting set operating a bank of lamps. The engine had a single air-cooled cylinder of 2½-in. bore and 5-in. stroke, provided with four detachable heads giving compression-ratios of 3.47 to 1.00, 3.87 to 1.00, 4.59 to 1.00 and 5.36 to 1.00. The usual method of testing was to compare a given fuel, with two reference-fuels, one of which was found by trial to detonate slightly more and the other slightly less than the given fuel. Various reference fuels were tried, such as blends of kerosene with benzol, aniline or xylidine. Fig. 5 shows the method of evaluating fuels in terms of two reference-fuels *A* and *B*. In this case, *A* was hexane plus a knock-inducing material, isopropyl nitrite, and *B* was hexane plus a knock-suppressing material, diethyl selenide. To compare the relative merits of knock-suppressors, they need only be added in varying proportions to the same gasoline, but it is evident, as pointed out by Dr. Graham Edgar[8], that the definite evaluation of motor fuels requires agreement upon a standard fuel and a standard blending-agent, or upon two suitable standard-fuels.

Sun Oil Co.

In 1925, A. L. Clayden published an account[9] of the manner in which he was using the bouncing-pin method for the rating of commercial motor-fuels. He uses a Regal one-cylinder 4 x 5-in. marine-engine with a special piston giving a compression-ratio of 5.5 to 1.0. The operating speed is 450 r.p.m., a fixed spark-setting is

[8] See *Industrial and Engineering Chemistry*, January, 1927, p. 145.

[9] See *Automotive Industries*, Nov. 12, 1925, p. 813.

[10] See *Industrial and Engineering Chemistry*, April, 1926, p. 334.

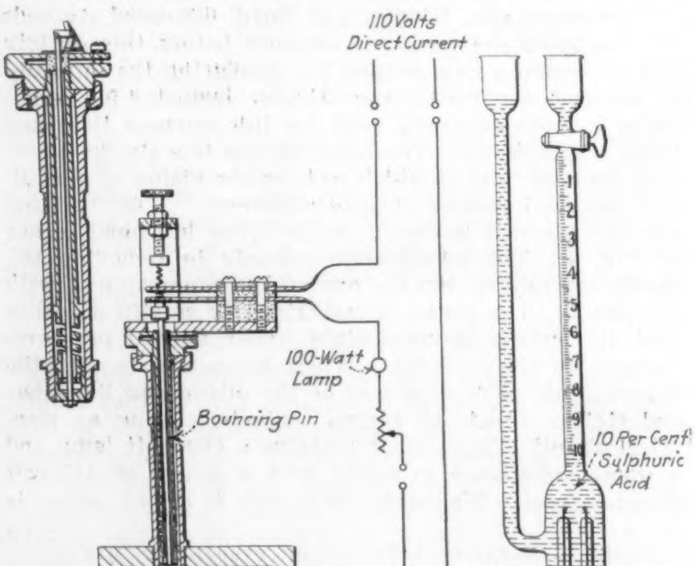


FIG. 4—MIDGLEY BOUNCING-PIN PRESSURE-ELEMENT AND KNOCK-INDICATOR

When Detonation Occurs, the Bouncing-Pin Is Thrown Free of the Piston, Strikes a Pair of Spring Contacts, and Closes an Electrical Circuit Containing a 100-Watt Lamp and a Water Voltameter in Series With a Source of 100-Volt Direct-Current. Whenever the Circuit Is Closed, Water Is Decomposed and Gas Is Produced. The Volume of Gas Collecting in the Graduated Arm of the U-Tube during a Given Interval of Time Depends on the Number and the Intensity of the Impulses Given to the Bouncing-Pin during That Time

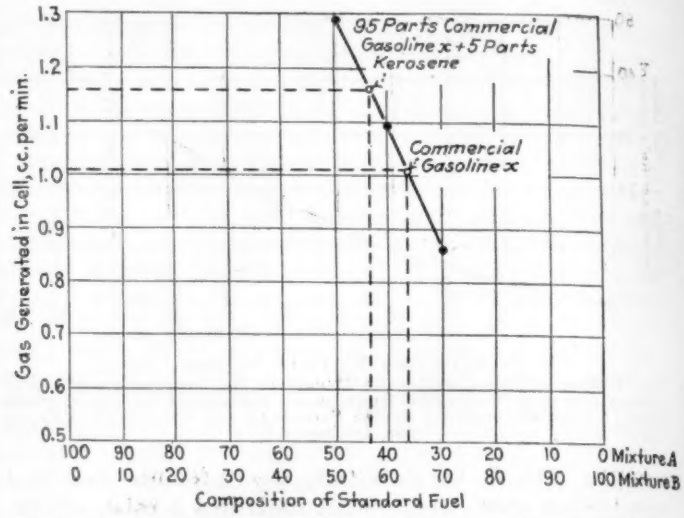


FIG. 5—COMPARISON OF FUELS WITH A SYSTEM OF REFERENCE FUELS

The Usual Method of Testing Was To Compare a Given Fuel with Two Reference Fuels, One of Which Was Found by Trial To Detonate Slightly More, the Other Slightly Less Than the Given Fuel. In This Case, Mixture *A* Was Hexane Plus a Knock-Inducing Material, Isopropyl Nitrite; Mixture *B* Was Hexane Plus a Knock-Suppressing Material, Diethyl Selenide

used, and the carbureter is adjusted until gas is evolved at the rate of 1 cc. in from 98 to 102 sec. when running on his reference-fuel. He then shifts to his unknown fuel and finds the time required to collect 1 cc. of gas. A check-run on the reference fuel is immediately made, and the test is discarded if this run gives a time differing by more than 2 sec. from that obtained on the initial run. The time required to collect 1 cc. of gas serves as an index-number. He states that 100 sec. represents a good gas, 60 sec. a thoroughly bad one, and 150 sec. a very good one. For still better fuels, a higher compression-ratio, or a different adjustment of the bouncing-pin contacts, must be used. To secure results that check, he finds it necessary to overhaul the bouncing-pin apparatus completely every few hours of running and to lubricate the engine by drip-feed, giving the piston the minimum of oil. He names the following factors as very important:

(1) Extreme cleanliness of all moving parts
(2) Clearance between the top of the pin and the lower contact-blade
(3) Clearance between the contact-points
(4) Accurate facing and cleaning of the contacts
(5) Absence of soot or lubricating-oil
(6) Regularity of the temperature of the instrument
(7) Spark-advance
(8) Mixture richness
(9) Humidity of the atmosphere
(10) Temperature of the atmosphere
(11) Perfect valve-setting

Ohio State University

A large amount of work done at the Ohio State University in 1922 and 1923 by Dr. W. H. Church[10], on the antiknock values of various compounds with respect to tetraethyl lead, was published in 1926. The apparatus and method did not differ materially from that used by Midgley and Boyd. The same paper, however, suggests a new method of estimating detonation intensity that is called the electrical conductivity method. Fig. 6 shows the electrical connections and a section of the special head used on the Delco engine for this work. Galvanometer deflections were observed increasing as the knock intensity increased and continuing for some time after audible detonation had ceased. Under the most steady conditions of operation, the galvanometer readings

were not constant, but the average deflection was obtained by averaging the readings at 10-sec. intervals over a period of several minutes. The results seemed to indicate a direct relation between the intensity of detonation and the ionization of the cylinder gases during combustion. Data published show an average deflection of 14.7 cm. for very intense detonation with equal parts of gasoline and kerosene, a deflection of 3.2 for moderate detonation with equal parts of gasoline and benzol, and a deflection of 1.6 for complete suppression of detonation with 30 per cent of gasoline and 70 per cent of benzol.

Armour Institute of Technology

Last winter, Professor Roesch presented to the Chicago Section of the Society a paper[11] on the method he is using to determine and express the relative antiknock value of motor fuels. He uses for test purposes a four-

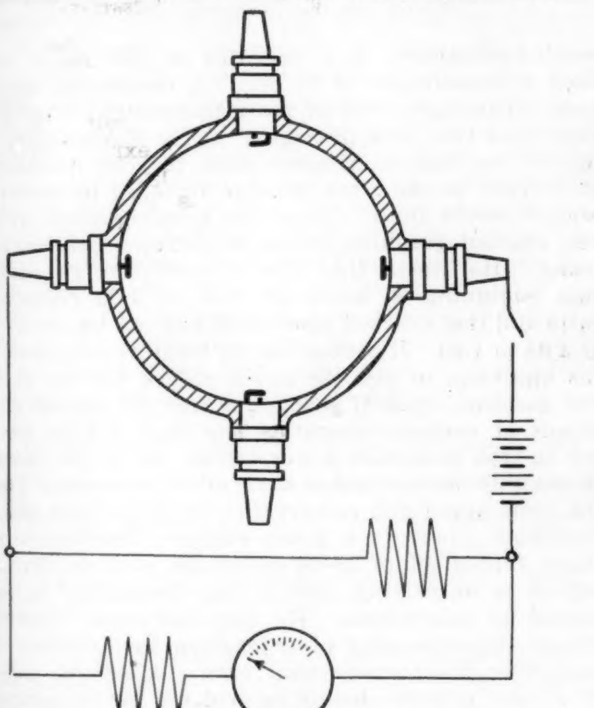


Fig. 6—Wiring Diagram of the Conductivity-Method Used by Ohio State University
Galvanometer Deflections Were Observed To Increase with the Knock Intensity and To Continue for Some Time after Audible Detonation Had Ceased. The Average of a Series of Readings Seemed To Indicate a Direct Relation between the Intensity of Detonation and the Ionization of the Cylinder Gases During Combustion. An Average Deflection of 14.70 Cm. Indicated Very Intense Detonation, 3.20 Cm. Moderate Detonation, 1.60 Cm. Complete Suppression of Detonation

cylinder automobile-engine having a compression-ratio of 4.5 to 1.0 and normally operating at a speed of 1000 r.p.m. at full throttle with a fixed carbureter-adjustment. Test runs are made at various spark-advances from dead-center, advancing step-by-step until the maximum permissible knock occurs. Four or five different intensities of knocking are distinguished by ear and for each the spark-advance and the brake mean effective pressure are obtained. Fig. 7 shows data on a commercial gasoline and a 40 to 60 benzol-gasoline blend. He uses either of two arbitrary index-numbers, devised by E. B. Phillips of the Sinclair Refining Co., to designate the knock intensity. The Phillips and Roesch index A is 100 times the ratio of the area to the right of the knock-intensity curve to the entire area of the rectangle bounded by the lines of 0-deg. and 60-deg. spark-advance and the lines of intensity A and D. Phillips and Roesch index B/C spark-advance signifies the mean value of the spark-advances required to give intensities B and C. Roesch also suggests several other ways of assigning numbers to his test results.

University of Michigan

Leslie, Brown and Hunn at the University of Michigan have published a description[12] of a bomb method for studying the rate of pressure-rise in the combustion of fuels and have adapted the method[13] to give information as to the relative antiknock value of certain straight-run and cracked gasolines. Their apparatus, shown in Fig. 8, consisted of a steel bomb, 2¾ in. in inside diameter and 7 in. long, equipped with a Bourdon gage, a Midgley optical pressure-indicator, and a thermocouple having its hot junction at the center of the bomb. The optical pressure-indicator was mounted over a gas-tight copper-oil diaphragm, to avoid leakage, and was equipped with an adapter that allowed the use of pistons of various diameters, so as to cover a wide range of pressures without exceeding the limit of the indicator-spring. The determination of antiknock characteristics is based on finding the proportion of nitrogen that must be added to a given gasoline-oxygen mixture to prevent the formation of peaks on the pressure-time curve. The smaller the quantity of nitrogen required to eliminate the peaks, the better the fuel is considered. By comparing pressure-time curves of particular fuels with those obtained under similar conditions for benzol, estimates of toluene value and of highest useful compression-ratio are obtained. One difficulty lies in distinguishing vibrations that originate in the pressure-indicator system itself from pressure peaks caused by detonation; and question may also be raised as to how accurately the thermocouple as used gives the temperature of the explosive charge at the instant of ignition.

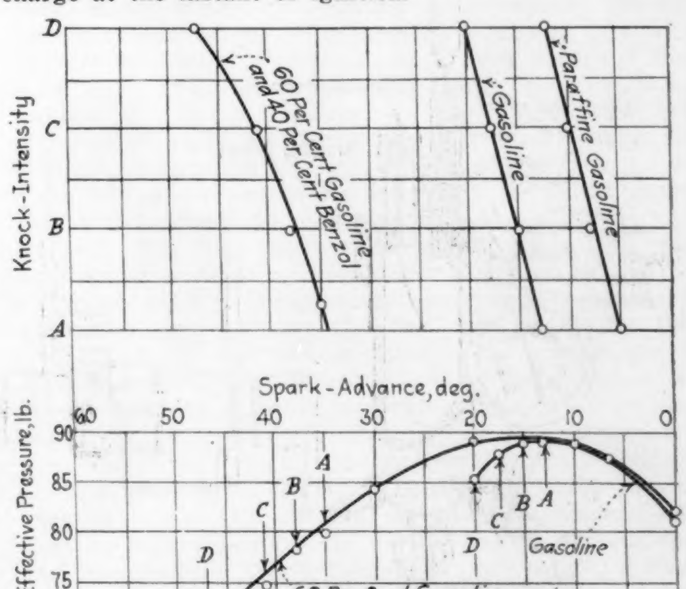


Fig. 7—Comparative Engine Data in Fuels, as Devised by E. B. Phillips and Used by Professor Roesch
Four or Five Different Intensities of Knocking Are Distinguished by Ear and for Each Intensity the Spark-Advance and Brake Mean Effective Pressure Are Obtained. The Curves Show the Data on a Commercial Gasoline and on a 40 to 60 Benzol-Gasoline Blend

[11] See The Journal, July, 1926, p. 17.
[12] See *Industrial and Engineering Chemistry*, April, 1925, p. 397.
[13] See *The Oil and Gas Journal*, Dec. 3, 1925, p. 62.

Leslie and Brown have also published data[14] on the relative antiknock values of benzol blends and of natural gasoline blends with straight-run Mid-Continent gasoline. For this work, they used a single-cylinder air-cooled Delco engine with a high-compression, 6.5 to 1.0, head, a standard Ford carbureter in place of the mixing-valve, the bouncing-pin indicator, and a prony brake for speed regulation. The engine was run at constant throttle, constant speed of 1200 r.p.m. and with fixed carbureter-adjustment. The fuels were compared on the basis of (*a*) spark-advance for intense knocking, 80 sec. to evolve 1 cc. of gas; (*b*) spark-advance for steady knocking, 100 sec. to evolve 1 cc. of gas; and (*c*) relative knock-intensity, rate of evolution of gas at a fixed spark-advance of 40 deg.

Kansas City Testing-Laboratory

Dr. Roy Cross, of the Kansas City Testing-Laboratory, is using a variable-compression engine in testing the detonation characteristics of motor fuels. This engine, as shown in Fig. 9, is a 4-hp. single-cylinder vertical Novo engine, rebuilt so that its compression-ratio can be increased by screwing down a piston into the combustion-chamber. It is operated at 500 r.p.m. with a fixed spark-advance of 30 deg. A mechanical explosion card apparatus is one of the attachments. Fig. 10 is a chart that Dr. Cross presented[15] at the Kansas City meeting of the American Association for the Advancement of Science to show the possible increase in power with certain motor fuels. These are a straight-run gasoline, two cracked gasolines and a 25-per cent benzol-gasoline blend. He states that the straight-run gasoline was just beginning to knock at 4.40 to 1.00 compression-ratio and that cracked gasoline *B* had not begun to knock at 4.85 to 1.00. It seems that he must be mistaken about the knocking, or else the power values for the straight-run gasoline, cracked gasoline *A* and the benzol-gasoline blends at compression-ratios less than 4.4 to 1.0 must not be true maximum-power values, for it has been very thoroughly demonstrated that all hydrocarbon fuels at the same speed and compression-ratio produce the same maximum power in a given engine. Furthermore, the sharp falling off of these curves as soon as detonation begins is surprising, unless the detonation is accompanied by preignition. He does not state whether he locates the beginning of detonation by listening or by inspecting the pressure-time card. A second paper by Dr. Cross[16] presents benzol equivalents for 14 commercial motor-fuels using a straight-run gasoline from Russell, Kan., as his reference fuel. He states that these results were obtained with his variable-compression engine, but does not explain whether the comparisons were made on the basis of (*a*) the compression-ratio at which a standard intensity of knocking is produced, or (*b*) the compression-ratio at which the greatest power is produced. Nor does he say what constitutes his standard of knock intensity.

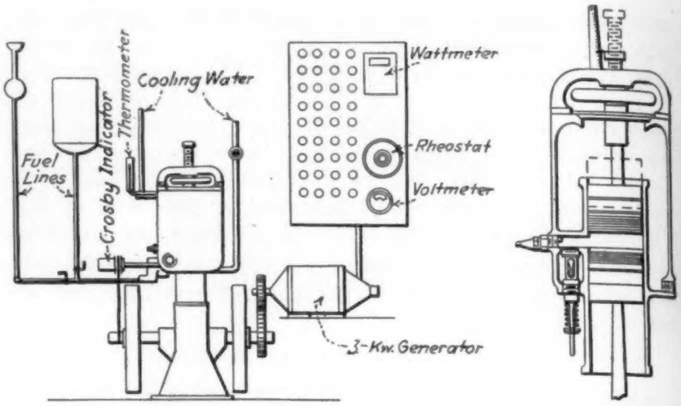


Fig. 9—Novo Engine Set-Up at the Kansas City Testing-Laboratory
A 4-Hp. Single-Cylinder Vertical Novo Engine Was Rebuilt so that the Compression-Ratio Could Be Increased by Screwing-Down a Piston into the Combustion-Chamber

Universal Oil Products Co.

Egloff and Morrell have devised a systematic procedure[17] for determining the unsaturated aromatic and naphthene hydrocarbons in gasoline that is carried out in the order stated. The reliability of this method was shown by applying it to several synthetic mixtures. From Ricardo's data they concluded that 5 per cent of unsaturated hydrocarbons was equivalent to 1 per cent of toluene when both were dissolved in paraffin hydrocarbons and, similarly that 4 per cent of naphthene was equivalent to 1 per cent of toluene. They then analyzed some straight-run and cracked gasolines and computed their aromatic equivalents. From the values thus found, Ricardo's highest useful compression-ratio for each of these gasolines was estimated. Engine tests were then

[14] See *National Petroleum News*, June 9, 1926, p. 45.

[15] See Kansas City Testing Laboratory Bulletin No. 22; and *The Oil and Gas Journal*, Jan. 7, 1926, p. 117.

[16] See Kansas City Testing Laboratory Bulletin No. 22; and *The Oil and Gas Journal*, Sept. 30, 1926, p. 26.

[17] See *Industrial and Engineering Chemistry*, April, 1926, p. 354.

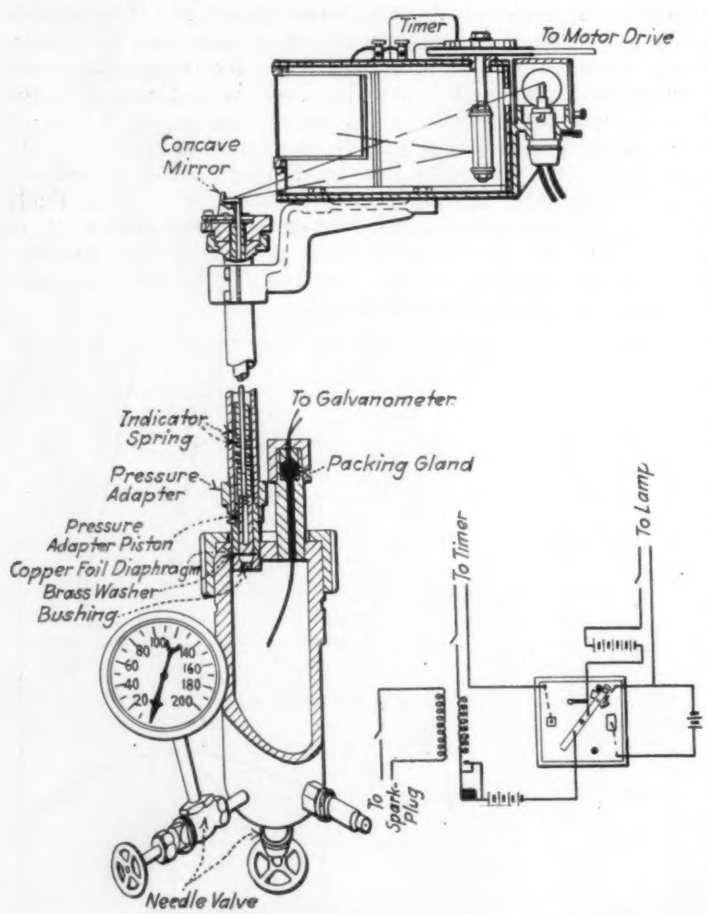


Fig. 8—Assembly of Bomb and Indicator, as Used at the University of Michigan
The Bomb Method for Studying the Rate of Pressure Rise during the Combustion of Fuel Was Adapted To Give Information as to the Relative Antiknock Value of Certain Straight-Run and Cracked Gasolines. The Determination of Antiknock Characteristics Is Based on Finding the Proportion of Nitrogen That Must Be Added to a Given Gasoline-Oxygen Mixture To Prevent the Formation of Peaks in the Pressure-Time Curve. The Smaller the Quantity of Nitrogen Required To Eliminate the Peaks, the Better the Fuel Is Considered

made of the cracked gasolines, the aromatic equivalents of which had been determined chemically, and of blends of a commercial gasoline with benzol. These tests were made by finding for each fuel the spark-advance required to produce a definite intensity of knock, judged by ear, in a four-cylinder motor-car engine of normal compression-ratio. The benzol blend equivalent in antiknock value to each of the cracked gasolines was estimated from the spark-advance data, and its aromatic equivalent was computed from the analysis of the commercial gasoline used. The aromatic equivalents of the cracked gasolines thus estimated checked those previously found to about 5 per cent in each case.

University of Iowa

Recent work at the University of Iowa by Olin, Read and Goos[18] fails to confirm the finding of Sims and Mardles[19] that colloidal solutions of lead or nickel are about equal to tetraethyl lead or nickel carbonyl in the suppression of detonation. Fig. 11 shows the arrangement of the testing apparatus. A two-cylinder high-compression racing-type motorcycle engine was used, together with a water-cooled prony-brake for absorbing the energy. The engine was operated at a constant speed, 1400 r.p.m., and constant spark-advance. A single thermocouple, brazed into a plug that replaced the priming-cup on one cylinder, was assumed to give the temperature of the fan-cooled cylinders. The brake mean effective pressure at which knocking begins with each of two fuels under identical operating-conditions was taken as a direct measure of their relative tendency to detonate. No information was given as to carbureter adjustment and it has been assumed that the comparison was based on the first audible detonation with each fuel. Critical knocking-loads were plotted against the cylinder-wall temperatures and, in all cases, these gave straight lines of constant slope.

[18] See *Industrial and Engineering Chemistry*, December, 1926, p. 1316.

[19] See Aeronautical Research Committee Reports and Memoranda No. 1021.

[20] See National Advisory Committee for Aeronautics Report No. 205.

[21] See The Journal, January, 1923, p. 11.

[22] See National Advisory Committee for Aeronautics Technical Note No. 101.

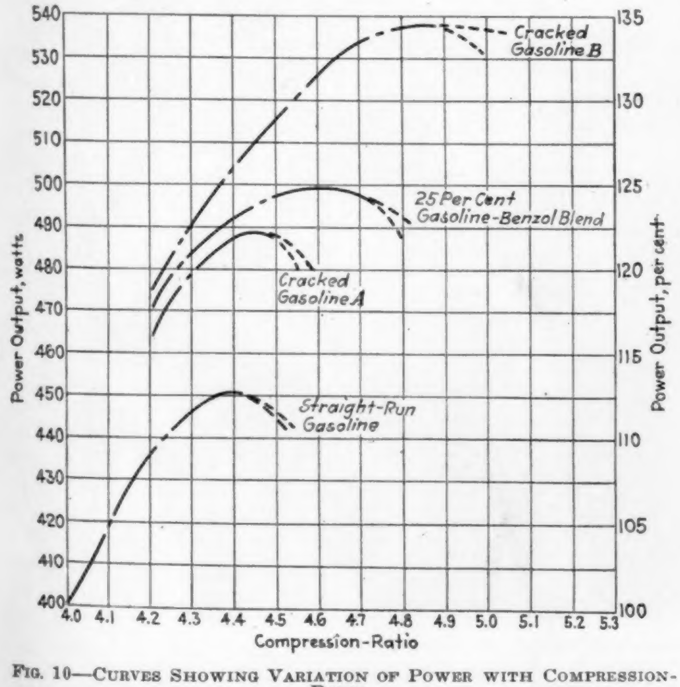


Fig. 10—Curves Showing Variation of Power with Compression-Ratio
The Fuels with Which Tests Were Made Are a Straight-Run Gasoline, Two Cracked Gasoline and a 25-Per Cent Benzol-Gasoline Blend

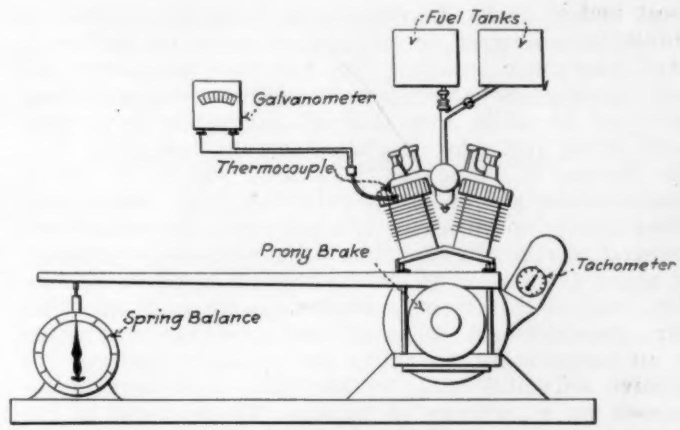


Fig. 11—Set-Up of Test Engine Used by the University of Iowa
A Two-Cylinder High-Compression Racing-Type Motorcycle Engine, With a Water-Cooled Prony-Brake for Absorbing the Energy, Was Operated at Constant Speed, about 4000 R.P.M., and Constant Spark-Advance. The Brake Mean Effective Pressure at Which Knocking Begins with Each of Two Fuels under Identical Operating-Conditions Is Taken as a Direct Measure of Their Relative Tendency To Detonate

The Bureau of Standards

The early work of the Bureau of Standards on engines of very high compression-ratio, referred to in connection with Ricardo's work, is described in reports[20] of the National Advisory Committee for Aeronautics on Fuels for High-Compression Engines and the Effect of Changes in Compression-Ratio on Engine Performance as well as in The Journal of this Society[21]. During the work on fuels for aviation engines, a device was developed for comparing moderate and more severe intensities of detonation. This consisted of a thin metal diaphragm clamped between two washers in a spark-plug shell. The time required to rupture a diaphragm of given thickness, when the diaphragm is exposed to the pressures in the engine cylinder, serves to measure the intensity of detonation. Aluminum discs ranging in thickness from 0.010 to 0.040 in. have been used for the most part. This device is more fully described in a publication[22] of the National Advisory Committee for Aeronautics entitled Comparing Maximum Pressures in Internal Combustion Engines.

In 1924, a routine test for comparing the power, economy and tendency to detonate of motor-car fuels was devised. The test plant, which is shown in Fig. 12, consists of a single-cylinder Liberty engine coupled to a Sprague electric dynamometer, together with auxiliary apparatus for metering the fuel and regulating the temperature of the cooling-water. The engine has a special crankshaft and crankcase, and the piston is crowned to give a compression-ratio of 6.3 to 1.0 instead of 5.3 to 1.0, otherwise standard Liberty-engine parts are used. A straight-run horizontal intake-manifold about 1 meter (39.37 in.) long is connected to a Claudel twin-jet carbureter, one side of which is blanked off. Positive mixture-control is secured by a valve in the fuel-line between the float-chamber and the jet. Fuel consumption is measured by timing the flow in a volumetric gage similar in principle to that used by Ricardo. Friction measurements are made by motoring the engine over, with the fuel and the ignition cut off, at the speed, throttle and water-temperature of operation. The full-throttle compression-pressure of the engine is about 175 lb. per sq. in., which makes considerable throttling necessary to avoid excessive detonation with

most motor fuels. In comparing fuels, the amount of throttling necessary to prevent excessive detonation is first determined for each fuel and then the power and fuel consumptions are measured with the engine further throttled to make sure that no detonation is present with either fuel. In practice, fuels are compared with the Bureau of Standards' laboratory supply of United States motor gasoline as a reference fuel, unless some other fuel is specified for this purpose. The usual reference-fuel requires throttling to a compression-pressure of about 120 lb. per sq. in. to prevent excessive detonation, and, at this throttle setting, yields from 21 to 22 i.hp., the exact value being affected somewhat by changes in air-temperature, humidity and engine-condition. The relative antiknock value of the fuel under test is expressed as percentage of increase, or decrease, in the maximum permissible power, and indicates closely the relative increase, or decrease, in the compression-pressure that the second fuel will stand without excessive detonation. The absolute results apply, of course, only to the Bureau of Standards engine and operating-conditions, but it is believed that the percentage figures are generally applicable.

Fig. 13 shows the actual results from a typical test. The crosses represent the fuel tested; the circles, the reference fuel. The spark-advance, about 30 deg., giving the maximum power at the optimum mixture-ratio with the reference fuel is used throughout, unless the fuel under test requires a distinctly different spark-setting for maximum power in the absence of detonation. At each throttle-setting with each fuel, at least five mixture-ratios are used, and the maximum power is determined from the curve obtained rather than by taking the value for any particular carbureter-setting. In this case, the maximum permissible power for the test fuel was 28.0 hp. as against 21.5 hp. for the reference fuel, a gain of about 30 per cent. The knock in the Liberty engine is readily estimated by ear, and the method of testing is as follows: The operator finds the throttle-setting that gives moderate detonation at approximately the carbureter-setting for maximum power and makes a mixture-ratio run, noting the intensity of detonation, if any, at each carbureter-setting. He next repeats the process at the same throttle-setting with the test fuel and notes whether more or less detonation occurs than with the reference fuel. If more detonation occurs with the test fuel, the throttle is closed until a match is secured. If less detonation occurs with the reference fuel, as in this case, the throttle is opened until the detonation seems to be of the same order as with the reference fuel at the original throttle-setting. The other two curves are for the power and economy runs, and the difference between them does not exceed the possible experimental error.

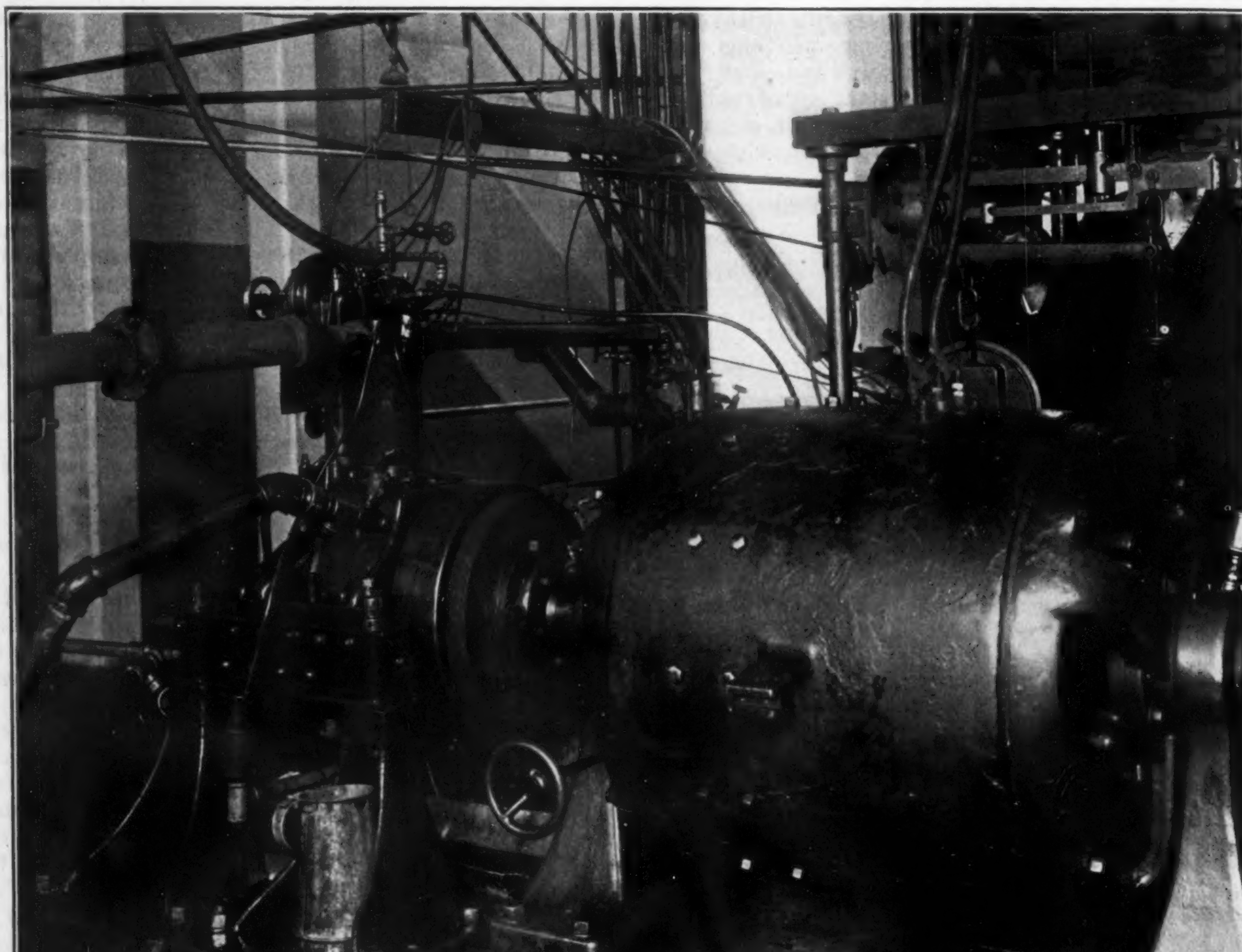


FIG. 12—BUREAU OF STANDARDS ENGINE SET-UP

The Testing Plant Consists of a Single-Cylinder Liberty Engine Coupled to a Sprague Electric-Dynamometer, Together with Auxiliary Apparatus for Metering the Fuel and Regulating the Temperature of the Cooling-Water. The Relative Antiknock Value of a Fuel under Test Is Expressed as Percentage of Increase, or Decrease, in the Maximum Permissible Power and Indicates Closely the Relative Increase, or Decrease, in the Compression-Pressure That the Second Fuel Will Stand without Excessive Detonation

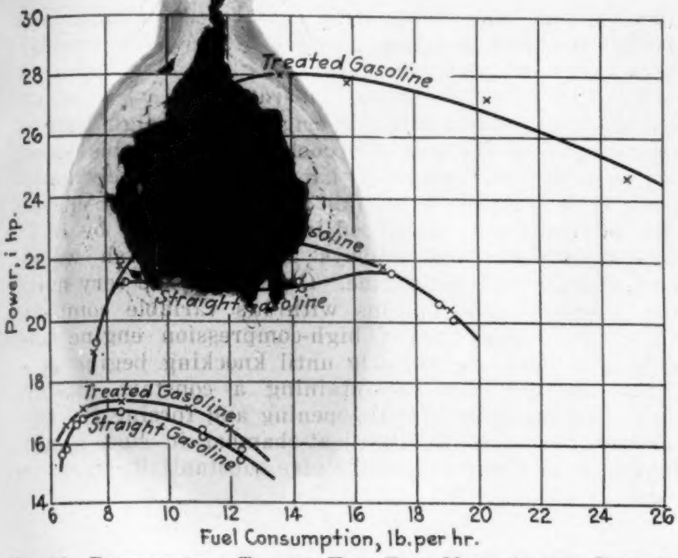


FIG. 13—RESULTS OF A TYPICAL FUEL-TEST MADE AT THE BUREAU OF STANDARDS

The Crosses Represent the Fuel Tested; the Circles, the Reference Fuel. The Spark-Advance, about 30 Deg., Giving the Maximum Power at the Optimum Mixture-Ratio with the Reference Fuel Is Used Throughout, unless the Fuel Under Test Requires a Distinctly Different Spark-Setting for Maximum Power in the Absence of Detonation. At Each Throttle-Setting with Each Fuel, at least Five Mixture-Ratios Are Used, and the Maximum Power Is Determined from the Curve Obtained rather than by Taking the Value for Any Particular Carbureter-Setting. In This Case, the Maximum Permissible Power for the Test-Fuel Was 28.0 Hp. as against 21.5 Hp. for the Reference Fuel, a Gain of about 30 Per Cent

More than a year ago, the Bureau of Standards was asked by the Bureau of Aeronautics of the Navy Department, to undertake the development of a fairly simple, easily operated device that could be used to test antiknock values when aviation gasoline was purchased for Navy use. Fig. 14 presents a sketch of a bomb built for this purpose. The bomb in its present state is a steel cylinder of 5-in. internal-diameter and 2 1/16-in. internal-height, having a portion of its removable head machined to form a diaphragm 2 in. in diameter and 5/32 in. thick. The temperature is controlled by electric heating-coils in a surrounding jacket and is measured by thermocouples placed just under the surfaces of the walls. Fuel is measured and injected into the bomb at atmospheric pressure by a precision pump the stroke of which is controlled by a micrometer-screw. Air is then admitted until a predetermined pressure has been reached. After a short wait, to assure vaporization and diffusion, the charge is ignited by a conventional spark-plug. If detonation occurs, a steel ball in contact with the diaphragm is thrown upward, the square root of the height of travel being taken as a rough indication of the violence of detonation. Under nondetonating conditions, the ball remains in contact with the diaphragm. The quantity of fuel injected is varied, in actual tests, until the point of maximum detonation is reached for given conditions of pressure and temperature. Results thus far obtained show considerable variation in individual readings under apparently identical conditions, but the averages of groups of readings with various fuels show differences of the same order as are obtained in the Bureau of Standards engine-test.

Neither the Air Corps nor the Bureau of Aeronautics seems to have published a definite test-method for determining the antiknock value of fuels, but the single-cylinder Liberty engine is used for such tests at McCook Field and at the Naval Aircraft Factory. At McCook Field, the difference in power caused by worse detonation with one fuel than with another has been used in comparing detonation intensity. In selecting aviation fuels, the problem is one of finding the best power and economy that can be obtained at a given compression-ratio. This involves varying the mixture-ratio and the spark-advance without much regard to detonation, so long as it is not dangerously severe.

DISCUSSION OF AVAILABLE METHODS

Nearly all these methods consist of engine tests, or rely on engine tests for their interpretation; and most of them involve a standard of knock intensity. Instruments for estimating knock intensity include:

(1) The air, for sound intensity
(2) Optical indicators, for the shape of the pressure-time curve
(3) The Midgley bouncing-pin apparatus, for the amount of gas, in cubic centimeters, evolved per minute
(4) A galvanometer, for electrical conductivity
(5) The diaphragm indicator, for the time required to shear a given diaphragm

In a few instances, fuels are rated according to the intensity of knocking that they produce under like operating-conditions in a given engine, as, for example, Clayden's index-number. In most cases, however, some engine-condition is altered to give the same intensity of knocking with different fuels. In variable-compression engines, the compression-ratio is varied to obtain the highest useful compression-ratio for each fuel, while, in other methods of testing, the compression-pressure is altered by supercharging a low-compression engine or throttling a high-compression engine, to obtain the maximum mean effective pressure for each fuel. Altering the spark-advance to secure equal intensity of detonation with various fuels in a constant-compression engine is a convenient, but less rational method of comparison, and the use of this method with multiple-cylinder engines can only be regarded as empirical. Still other methods involve finding, more or less by trial, the amount of knock suppressor, or knock inducer, that must be added to a standard reference-fuel to make it equivalent in antiknock value to the fuel under test. Results obtained by such methods may be quite independent of engine characteristics and operating conditions, but this merely shifts the uncertainty from the engine to the reference fuel. The

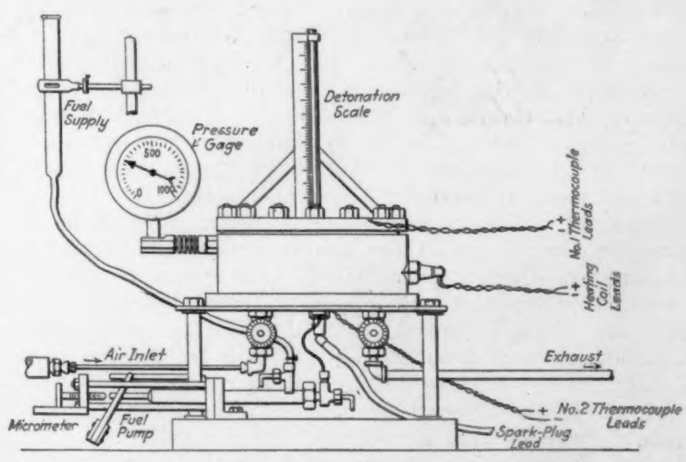


FIG. 14—DETONATION BOMB UNDER DEVELOPMENT AT THE BUREAU OF STANDARDS

A Measured Amount of Fuel at Atmospheric Pressure Is Injected and Air Is Admitted Until a Predetermined Pressure Has Been Reached. After the Mixture Has Become Thoroughly Vaporized and Diffused, the Charge Is Ignited by a Conventional Spark-Plug. If Detonation Occurs, a Steel Ball in Contact with the Diaphragm Is Thrown Upward, the Square Root of the Height of Travel Being Taken as a Rough Indication of the Violence of Detonation. Under Non-Detonating Conditions, the Ball Remains in Contact with the Diaphragm

plan offered by Egloff and Morrell for estimating the highest useful compression-ratio of a fuel from the results of chemical analysis is ingenious, but too indirect for consideration as a routine method. On the contrary, a simple bomb-method giving, on small samples of fuel, results that can be correlated with the antiknock value of the fuel as determined by engine tests would be of great value.

THE DISCUSSION

CHAIRMAN THOMAS MIDGLEY, JR.[23]:—Several times during the paper the colloidal-metal suppression of knock was mentioned. So far as I know, that statement has been published by a couple of investigators, but no one else has ever been able to get the slightest indication of the suppression of knock by colloidal metals. You can form your own opinion. I merely mention that fact, for I do not like to see those things go too far and become too thoroughly believed.

DR. G. G. BROWN[24]:—As the use of bombs at the University of Michigan has been referred to, a few points from our experience may be interesting. We worked with a longer bomb than did Mr. Cummings but, for a number of reasons, have now abandoned the use of a bomb for determining the antiknock properties of fuels. It is open to all the criticisms that Mr. Cummings has mentioned. We found, however, that the Midgley indicator, when properly adjusted, was equally satisfactory as a pin or a ball resting on a diaphragm gives a definite record of the pressure-rise.

Probably the most important conclusion regarding bomb explosions is that the explosion may be one of two types, one of which is the true detonation wave as investigated by Dixon in England; the other seems to be some form of auto ignition, as reported by Woodbury[25] before this Society some years ago. Apparently, benzol will develop a detonation wave as readily as normal octane. Auto ignition of some form will occur under different conditions, particularly when using air and when the surface of the bomb is hot. This type of reaction appears similar to the type of explosion that takes place in the engine, and the relative knocking-tendency of fuels determined under these conditions may be similar to the knocking intensity as determined in the engine.

For this reason, the bomb will occasionally give results that are absolutely incompatible with engine results. It is possible that, by carefully selecting the dimensions of the bomb and carefully controlling other factors, Mr. Cummings has been able to assure a type of explosion that is similar to that developed in an engine. If so, this bomb promises to be a very useful piece of equipment, at least for preliminary tests.

Personally, I have confidence in the results of bomb tests only when conditions are such that the knocking tendency is directly proportional to the rate of rise of pressure of the fuel. In testing different types of fuel, such as alcohol, benzol, normal paraffins, and trick paraffins, such as tri-methyl pentane, I believe the best results can be obtained only in an engine.

R. N. DUBOIS[26]:—All we can say, in answer to Dr. Brown's report that he obtains two different types of explosion with benzol in the bomb, is that our apparatus seems to give, in all cases, the same type of explosion, one comparable with engine-performance, with benzol and with aviation gasoline over a very considerable range of initial temperatures.

R. E. WILSON[27]:—In our labora[illegible] view of unsatisfactory results with the orig[illegible]light engine, on account of the variable cool[illegible]ble speed, we came to the conclusion that [illegible]ely necessary to do antiknock testing [illegible]d engine. The method finally developed in[illegible] by D. P. and E. R. Barnard employs a [illegible]sh water-cooled single-cylinder engine. O[illegible] very much like those Ricardo obtains with his variable compression. We simply use a high-compression engine and gradually open the throttle until knocking begins at a given air-fuel ratio, maintaining a constant air-fuel ratio with variable throttle-opening and forcing the carbureter. We also fix the float-chamber in such a way that fuels of different gravity give substantially the same ratio.

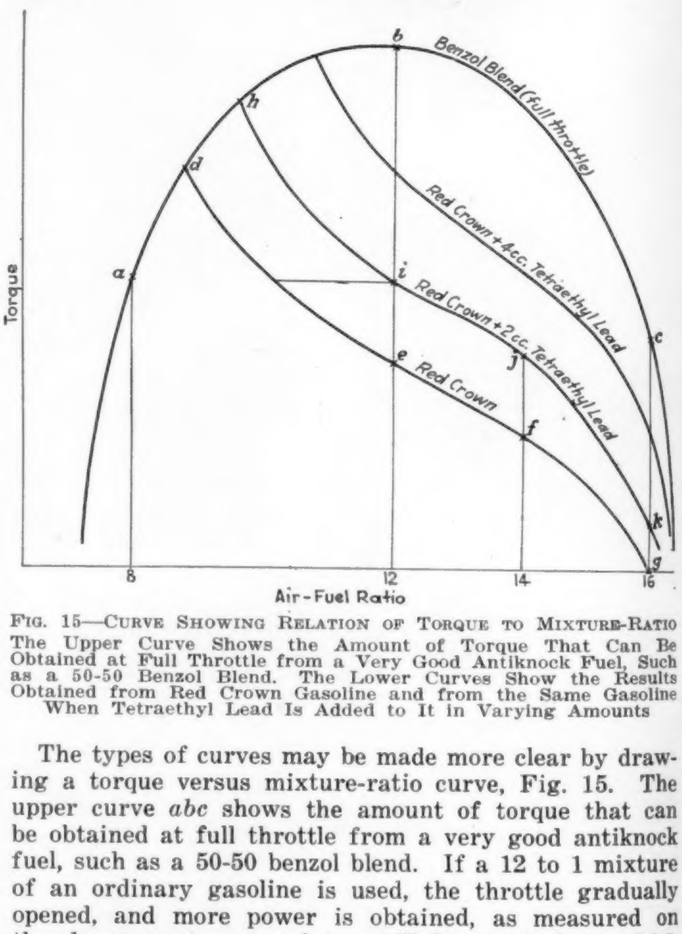


FIG. 15—CURVE SHOWING RELATION OF TORQUE TO MIXTURE-RATIO
The Upper Curve Shows the Amount of Torque That Can Be Obtained at Full Throttle from a Very Good Antiknock Fuel, Such as a 50-50 Benzol Blend. The Lower Curves Show the Results Obtained from Red Crown Gasoline and from the Same Gasoline When Tetraethyl Lead Is Added to It in Varying Amounts

The types of curves may be made more clear by drawing a torque versus mixture-ratio curve, Fig. 15. The upper curve *abc* shows the amount of torque that can be obtained at full throttle from a very good antiknock fuel, such as a 50-50 benzol blend. If a 12 to 1 mixture of an ordinary gasoline is used, the throttle gradually opened, and more power is obtained, as measured on the dynamometer, a point *e* will be reached at which detonation begins. We might call this the highest useful torque at that mixture-ratio. Another point at 14 to 1 is *f*. It is not necessary to do this for every fuel, but it establishes a base-line. What we get is a curve of the general nature *defg*. Then, if 2 cc. of tetraethyl lead is added to the gasoline and the throttle is opened till knocking begins, another curve, *hijk* is obtained, parallel to but a considerable distance above it, showing the gain in useful torque due to the antiknock fluid. The shapes of the curves for most fuels are the same. The untreated fuel, for example, at a 10 to 1 ratio has or will develop the same torque without knocking as will the better fuel at a somewhat leaner mixture-ratio. If the mixture is enriched, less knocking is produced even with such a fuel. This brings out the importance of

[23] M.S.A.E.—Thomas & Hochwalt Laboratories, Dayton, Ohio.
[24] Professor of chemical engineering, University of Michigan, Ann Arbor, Mich.
[25] See THE JOURNAL, March, 1921, p. 209.
[26] S.M.S.A.E.—Associate engineer, Bureau of Standards, City of Washington.
[27] M.S.A.E.—Member research council, Standard Oil Co. of Indiana, Whiting, Ind.

comparing two different fuels at the same mixture-ratio. A great deal of the misunderstanding of results that arises in comparing ordinary fuels with benzol blends is due to the fact that some carbureters give marked enrichment with benzol blends. Therefore, the benzol blends show up more favorably than if the comparison were made at constant mixture-ratio.

For routine testing, all that is necessary is to set the carbureter and gradually open the throttle until audible knocking begins. If there is difficulty in picking that place, a bouncing-pin indicator would be useful. We believe we can pick it as closely by ear as is necessary for all ordinary testing, so we have not used the indicator thus far. It comes very close to measuring what the man driving the car is interested in, namely, how far can he open the throttle before knocking begins? How much can he get out of the engine before it talks back? We believe, therefore, that this method has come close to giving fuels their proper rating for service conditions.

H. A. HUEBOTTER[28]:—I notice that Mr. Cummings, in his description of several of these tests, says that the engine spark-advance was kept constant. I wonder whether that is the general practice in these laboratory tests. It is not common with us at Purdue University, for we change the ignition timing with every change in speed, load, or mixture-ratio, to get the best power. Some fuels apparently detonate because they have a short lag from the ignition-point to the point of maximum pressure. Other fuels might have a longer lag. It is hardly fair to test both those fuels with the same timing of the spark.

H. K. CUMMINGS:—I should like to point out one thing about that; it depends very much on the type of test. If, like the Bureau of Standards, you are interested only in the maximum power of a series of mixture-ratios, the question is, whether this maximum power is appreciably affected by the spark-advance. The spark-advance giving the maximum power is fairly definite and varies little for constant speed within a moderate range of throttle settings. On the other hand, if readings are taken that involve a variation in speed, it is possible that the comparison may be affected, unless the optimum spark-advance is taken for every reading. That is the ideal thing in any case. We omitted doing it because we did not consider it to be of sufficient importance to justify the additional tests required.

MR. HUEBOTTER:—That has been our experience, substantially. We find that, around the high-power mixture, the engine-performance is not sensitive to spark change. When we conduct economy runs and get down to the lean mixtures, small changes in the spark timing will affect the torque appreciably.

PROF. DANIEL ROESCH[29]:—It may be worthwhile to look into the factors that influenced the adoption and development of the spark-advance method of testing at the Armour Institute of Technology and also to inspect some of the advantages and limitations of the method. In developing this method of test, it was recognized that rational methods are preferred to empirical methods.

The conditions surrounding the spark-advance method of testing detonation meet almost exactly those with which the ultimate user of the fuel must contend, and from this method of testing the consumer's point of view of what is good fuel with regard to knocking seems to be accurately duplicated with respect to knock intensity, although possibly not exactly with respect to pressure intensity. The consumer's point of view, however, is with respect to the noises accompanying detonation and not directly with respect to the pressures. The consumer seems to leave the pressure consideration and the attendant endurance-characteristic of the engine very much to the engineer. From our experience, the engineer needs no apology for the endurance characteristic of the passenger-car engine when it is subjected to detonation. Our engine operates frequently for 8 hr. per day at 1000 r.p.m. and wide-open throttle, with considerable knocking and occasional spark-advances up to 60 or 80 deg. early. This is equivalent to about 160 miles of car travel up a 10-per cent grade. From consideration of the intensity of the noises produced, as compared to the intensity of the pressures produced, it seems that the car-user's measure of what is going on in the engine with respect to noise would automatically prevent excessive pressures, to the serious detriment of the life of the engine. From the ultimate user's point of view, the test method seems rational, since he uses a fixed-compression engine and varies the spark.

Furthermore, it is believed that the theory regarding detonation, which shows the maximum pressures accompanying detonation to be developed after the ignition-point, is logical. If by advancing the spark, abnormally in some cases, this detonating wave can be produced earlier in the cycle, possibly earlier in the power stroke, or even near the end of the compression stroke, it would seem that the conditions are somewhat parallel, and the spark-advance method is therefore along the lines of the method using advanced compression to produce the detonation. The chief difference seems to be that the building-up of the pressure and the occurrence of detonating phenomena take place a little earlier in the stroke. The time-element between ignition and detonation apparently is shorter with the spark-advance method, because of the decreasing volume in the combustion-chamber in this case as compared with the increasing volumes during the expansion stroke for cases of detonation occurring in normal engine-operation after dead-center. Another difference is that spark-advance tests are usually made with lower-compression engines than are the variable-compression tests. The volume of the combustion-chamber is therefore larger in this case than in the case of high-compression engines. The fundamental factors, however, that accompany detonation are believed to be present in either case, and the relation is believed to be determinable for the spark-advance tests. although this may involve many assumptions that will detract from the usefulness of such a determination. It is evidently accepted that we may write

$$\text{Compression} = f \text{ (the knock)}$$

and it seems from the above that the

$$\text{Spark-advance} = f \text{ (the knock)}$$

may be written, if the necessary factors can be written into the right-hand member of the equation. It seems that the method of test has undeveloped rational features.

One of the features of this method is that it differentiates between combustion-chamber designs. This feature, I believe, is common to most other methods of engine testing for antiknock. This is an advantage in comparing engines, but causes confusion in comparing fuels.

It is hardly to be expected that any one method of testing will cover all requirements for antiknock evaluation, although a standard method or standard methods of testing are highly desirable.

One of the disadvantages of the spark-advance method

[28] M.S.A.E.—Associate professor of gas engineering, Purdue University, Lafayette, Ind.

[29] M.S.A.E.—Associate professor of gas engineering, Armour Institute of Technology, Chicago.

is that it involves the personal equation in determining the knock intensity. Some other methods have this same characteristic, because of the setting of the spark for a constant knock. This becomes a serious handicap in some instances in spite of the ability to check unknown fuels very accurately.

Another disadvantage of the method is that an engine of constant volume-ratio has a limited range of fuels that can be tested without changing the compression. This range for a 4½ to 1 volume-ratio corresponds to about 40 to 50-per cent benzol-equivalent in a paraffin fuel, while the better fuels can be examined only for lesser amounts of benzol equivalents, depending upon the antiknock value of the raw gasoline.

Relative Prices of Gasoline as Determined From Audibility Antiknock Tests

One of the uses of evaluated antiknock values is the determination of fair relative prices of raw and blended fuels. For a number of years the price of gasoline for automobile engines has varied uniformly, irrespective of the characteristics of the fuel. Gasolines are now avail-

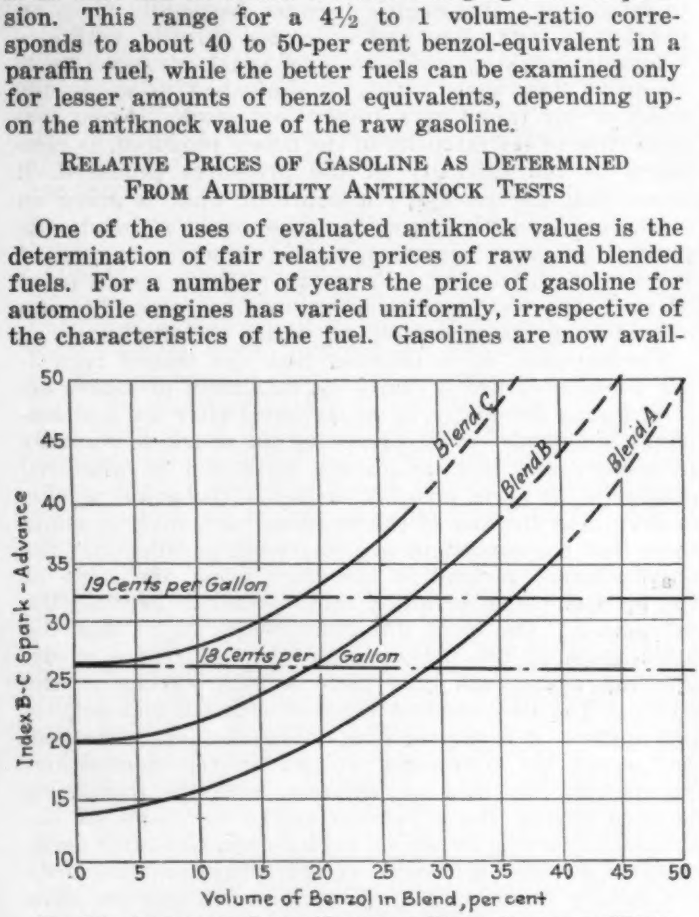


FIG. 16—ANTIKNOCK INDEX-VALUES OF THREE GASOLINES WHEN BLENDED WITH BENZOL

Fuel *A* Is a Straight-Run Gasoline of High End-Point; *B*, a Fuel Somewhat Better in Antiknock Value; and *C*, a Cracked Fuel That Has the Least Tendency of the Three To Knock

able for general distribution, however, that are sold at a premium of from $0.03 to $0.05 per gal. over the market price of the standard product. These fuels have been offered in increasing numbers principally because the public is willing to pay more for one fuel than for another, provided it has certain desirable characteristics. These distinguishing properties may be in the form of improved starting-qualities, more complete combustion, better antiknock values, or other desirable characteristics that may soothe the engine, or result in more power, the formation of less carbon, or less crankcase-oil dilution.

The following price-analysis of various gasolines and blends is based only on their antiknock properties in an engine of fixed compression-ratio as determined by a method of testing developed in the automotive laboratory of the Armour Institute of Technology[30]. The results may vary somewhat from those obtained when the fuels are compared by other methods of testing. The method used seems reasonable, however, as a basis of price determination from the car-user's viewpoint of antiknock values, since it is a method of direct application and is made

[30] See THE JOURNAL, July, 1926, p. 17.

TABLE 2—RELATIVE VALUES OF RAW GASOLINES, BASED ON AN EQUAL ANTIKNOCK-VALUE

Gasoline Used	*A*	*B*	*C*
Index "B-C" Spark-Advance	26	26	26
Proportion by Volume of Raw Gasoline to Benzol	71/29	79/21	100/0
Total Value of 100 Gal.	$18.00	$18.00	$18.00
Cost of Benzol, at $0.25 per Gal., per 100 Gal. of Blend	$7.25	$5.25	0
Value of Raw Gasoline per 100 Gal. of Blend	$10.75	$12.75	$18.00
Value of Raw Gasoline per Gallon, cents	15.1	16.1	18.0

under conditions that are practically identical with those which the consumer uses and by which he judges the fuel. It is also recognized that there probably will be variations in the comparative results when examination is made under different mixture-ratios, mixture-temperatures, wet or dry mixtures, atmospheric-conditions of temperature, pressure and humidity, carbon-deposit, combustion-chamber shape, load and speed of the engine, and engine design. The above are maintained constant so far as possible for this work.

In case it is desired to determine the comparative price of three gasolines that are to be mixed with benzols, three series of tests must be made. Representative summary data for these three fuels are graphically shown in Fig. 16 based on *B-C* knock intensity. Other knock intensities, such as the first indication or *A* knock, or other intensities up to a sharp knock, like the *D* knock, may be used. The comparative values will not necessarily be the same when different knock-intensities are used. Fuel *A* is a straight-run gasoline of high end-point; *B*, a fuel somewhat better in antiknock value; and *C*, a cracked fuel that has the least tendency to knock of the three fuels. Their respective knock-characteristics are 14, 20 and 26-index *B-C* spark-advance.

Tables 2 and 3 show data taken from Fig. 16, and the computations made to determine the relative price of each of three raw fuels as it is based on their relative antiknock values when determined by this test method. The method of computation is obvious from the notes in the tables.

Two conditions of antiknock values have been assumed. Table 2 is based on a required antiknock value of 26; Table 3 on a required antiknock value of 32. The relative prices as determined are believed to be fair and impartial for the conditions assumed and the method to be adaptable to many problems. The values of each of the three blends having an index-value of 26 have been placed at $0.18 per gal., and the three blends shown in Table 3 having an antiknock index-value of 32 have each been given an arbitrary price of $0.01 more, or $0.19 per gal. Obviously, fuels having higher index values are of greater value. A closer inspection of the data in Tables 2 and 3 shows that the relative values of raw gasoline that are to be blended with benzol for specific antiknock-qualities depend on the condition of blending. The par-

TABLE 3—RELATIVE VALUES OF RAW GASOLINES, BASED ON AN EQUAL ANTIKNOCK VALUE

Gasoline Used	*A*	*B*	*C*
Index "B-C" Spark-Advance	32	32	32
Proportions by Volume of Raw Gasoline to Benzol	63/37	72/28	81/19
Total Value of 100 Gal.	$19.00	$19.00	$19.00
Cost of Benzol, at $0.25 per Gal., per 100 Gal. of Blend	$9.25	$7.00	$4.75
Value of Raw Gasoline per 100 Gal. of Blend	$9.75	$12.00	$14.25
Value of Raw Gasoline per Gallon, cents	15.5	16.7	17.6

ticular gasoline that requires 10 per cent or less of benzol is apparently handicapped; or, in other words, the first 10 per cent is relatively less effective than additional 10-per cent increments.

The first 10 per cent of benzol gives a smaller increase in index-value than does additional 10-per cent increments. This characteristic is also influenced by the fact, pointed out[21] by S. W. Sparrow, that the first 10 per cent must act with 90 per cent of raw gasoline, but the 30 or 40 per cent acts only with 70 or 60 per cent of the raw fuel respectively.

MR. CUMMINGS:—Professor Roesch uses a fallacious argument when he states that his method seems rational from the ultimate user's point of view, since he uses a fixed-compression engine and varies the spark. The average automobile-driver normally operates at a fairly constant spark-advance and finds that certain fuels knock when he opens the throttle wide enough. To get rid of the unpleasant sound, he then retards the spark, and by doing so loses some power. If the engine in question knocks readily enough, he will find that the knocking appears with poor fuels before he gets the throttle wide open with normal spark-advance. For such an engine and such fuels, the relative antiknock-value is indicated, as in the Bureau of Standards test, by the relative amount of throttling necessary to prevent detonation, or by the maximum power obtainable at such throttle-settings. Neither of these qualities can be readily measured by the motorist, so he occasionally resorts to estimating the relative antiknock-value of various fuels in his particular engine by the purely empirical method of comparing the spark-advances that the different fuels allow without knocking under approximately constant operating-conditions. It is this empirical test which Professor Roesch has taken into the laboratory and on which he gets reproducible results by careful control of operating conditions.

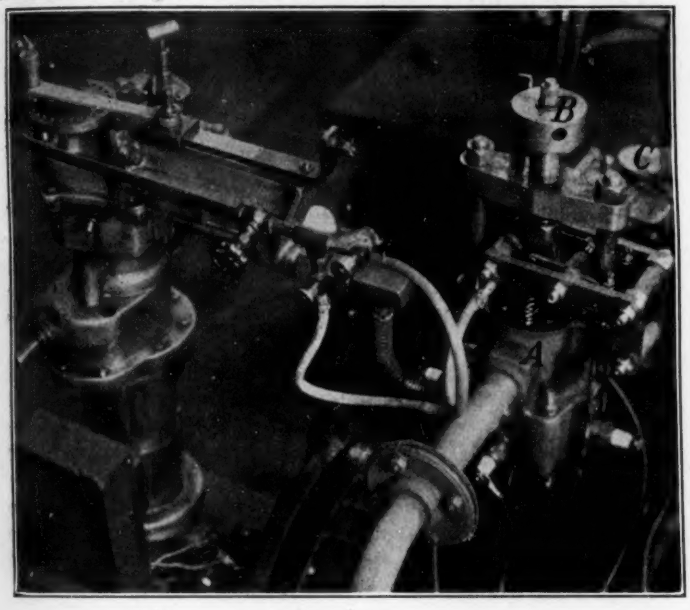


FIG. 17—VARIABLE-COMPRESSION ENGINE CONSTRUCTED AT OHIO STATE UNIVERSITY

A Cylinder of 3 5/16-In. Bore Is Bolted in a 2½ x 5-In. Delco Engine in Place of the Regular Cylinder-Head. Within the Cylinder Is Mounted a Piston Carrying the Valves. The Piston Is Adjusted by a Micrometer-Screw a Total of about ⅝ In., Which Gives Compression-Ratios Ranging from 3½ to 1 to 6½ to 1. The Valve Timing and the Valve Clearance Are Not Changed Materially by Moving This Valve-Piston, Since the Valve Rocker-Shaft Is Automatically Adjusted through a System of Levers

The idea of basing the price of antiknock fuels on their relative antiknock value, assuming that the fuels are equivalent as regards volatility and other desirable characteristics, is an interesting suggestion, irrespective of the particular method employed to determine the antiknock value. A $0.05 premium represents a price increase of about 25 per cent, and it seems doubtful whether a price increase of more than 10 per cent can be justified on the basis of antiknock value alone, until automobile-engine compression-ratios have been materially increased.

PROF. W. E. LAY[22]:—The University of Michigan has recently acquired a variable-compression engine similar to the Ricardo engine. In addition to the variable-compression feature, each event in the valve timing may be changed over a wide range by an ingenious valve-mechanism. The valve lift may be changed without affecting the clearance or the timing. All these changes may be made without stopping and dismantling the engine or even changing any other operating condition, and are indicated by Veeder counters. The bore and stroke of the engine are those of the Liberty aviation-engine. It has four overhead valves, with three openings for spark-plugs or indicators. The combustion-chamber cooling-jacket is separate from the cylinder-wall jacket, making possible the changing of the cylinder-head temperatures while maintaining constant piston-friction. A double carbureter and fuel system is arranged so that a change from one fuel to another may be made at any time. Both the air and the fuel are measured, the air by a calibrated Venturi-meter, with an efficient surge-chamber and elec-

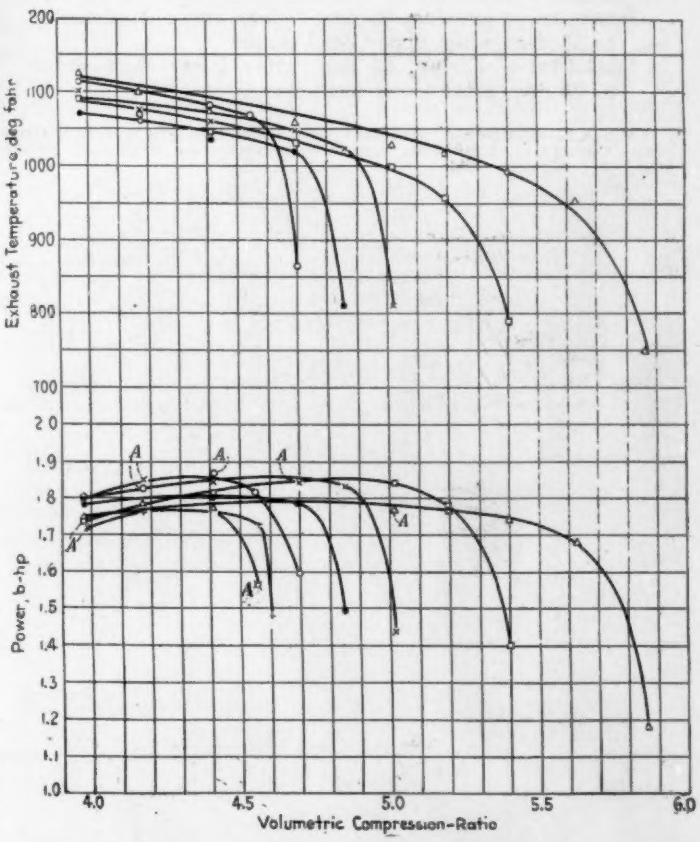


FIG. 18—CURVES SHOWING THE EFFECT OF INCREASING THE COMPRESSION-RATIO OF VARIOUS FUELS

Seven Different Fuels Were Used. The Letter *A* Indicates the Compression-Ratio at Which the Detonation or Preignition First Becomes Audible. The Break in the Horsepower Curve Shows When Detonation Really Begins

[21] See National Advisory Committee for Aeronautics Report No. 232.

[22] M.S.A.E.—Associate professor of mechanical engineering, University of Michigan, Ann Arbor, Mich.

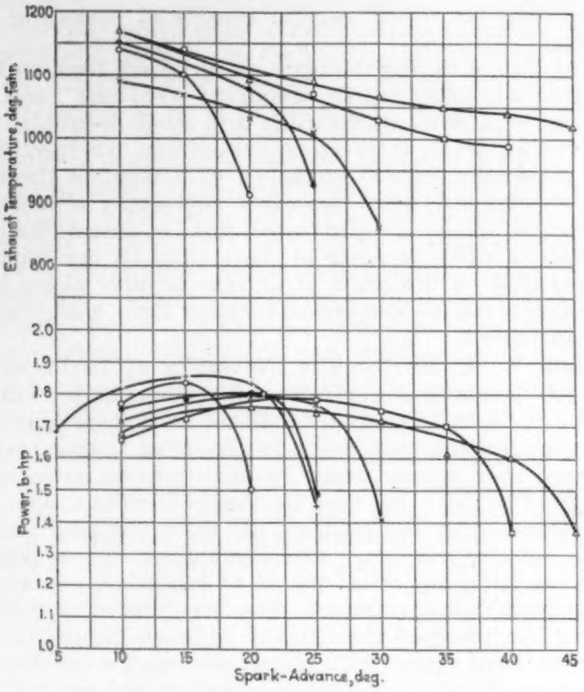


FIG. 19—CURVES SHOWING THE EFFECT OF CHANGING THE SPARK-ADVANCE WITH VARIOUS FUELS

The Compression-Ratio Was Maintained Constant at 4.55 to 1.00 for All Fuels. The Fuels Show Substantially the Same Relative Behavior as Those of Fig. 18

tric heater interposed between it and the carbureter intake. The variable features of the engine may be summarized as follows:

- Compression-ratio, 3.3 to 1.0 up to 15.0 to 1.0
- Intake-valve opening, 35 deg. before upper dead-center to 13 deg. after upper dead-center
- Intake-valve closing, 25 deg. after lower dead-center to 78 deg. after lower dead-center
- Exhaust-valve opening, 10 deg. before lower dead-center to 60 deg. before lower dead-center
- Exhaust-valve closing, 27 deg. before lower dead-center to 23 deg. after upper dead-center
- Valve lift, 0.180 to 0.460 in.

An ambitious program has been laid out, and a year or two may bring out something of interest and real worth.

H. M. JACKLIN[33]:—Several variable-compression engines have been mentioned, and at least one has been shown at this meeting. Fig. 17 shows a view of another engine that we have constructed at a cash outlay of between $35 and $40. A cylinder of 3 5/16-in. bore, which is bolted on a Delco 2½ x 5-in. engine in place of the regular cylinder-head, is shown at *A*. Within the cylinder is mounted a piston carrying the valves. The piston is adjusted by the micrometer-screw *B* a total of about ⅝ in., which gives compression-ratios ranging from 3½ to 1 to 6½ to 1. The valve timing and valve clearance are not changed materially by moving this valve-piston, since the valve rocker-shaft is automatically adjusted through the system of levers shown. This little test-unit, including the indicator and a small dynamometer and air-measuring tanks, which are not shown, has enabled us to do some successful testing. The small dynamometer is used so that the regular Delco generator may be cut-out and accurate results obtained as to the horsepower developed. The shape of the combustion-chamber is not changed materially when the compression-ratio is changed in this scheme, so that accurate results may be secured.

The influence of the air-to-fuel ratio has been discussed with reference to detonation. We have found that this ratio has a very great effect, the lean mixtures generally showing less detonation. Consequently, we have been particular to try to have as nearly the same air-to-fuel ratio for all fuels as it was possible to obtain. The needle-valve of the carbureter is provided with a large disc, *C*, which enables the needle-valve to be calibrated for each particular fuel. The engine is run with at least

[33] M.S.A.E.—Assistant professor of automotive engineering, Ohio State University, Columbus, Ohio; and consulting engineer, Power Mfg. Co., Marion, Ohio.

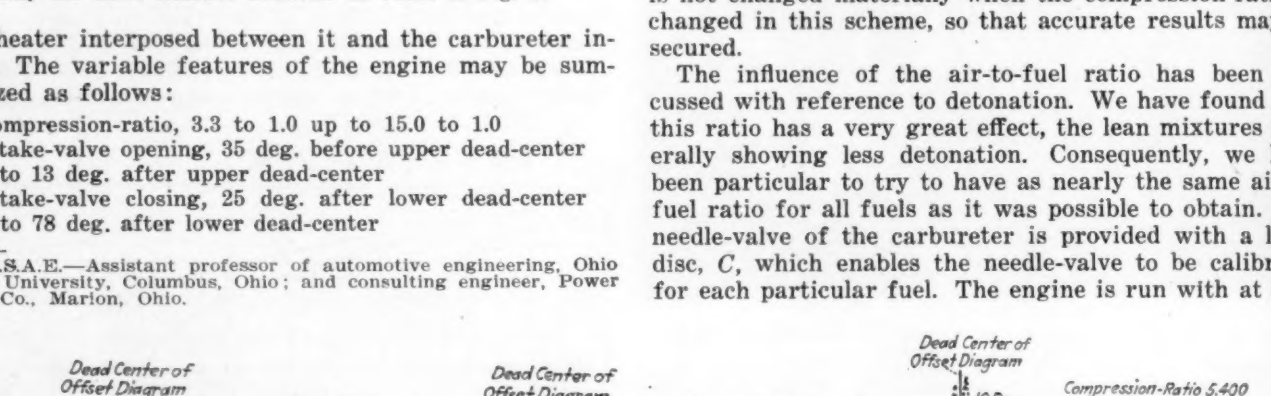


FIG. 20—DIAGRAMS FROM 2½ X 5-IN. VARIABLE-COMPRESSION ENGINE USING THE "TRIANGLE" FUEL

The Volumetric Compression-Ratio Is Indicated on Each Diagram as Is Also the Character of the Detonation. The Spark-Advance Was 20 Deg. and the Air-to-Fuel Ratio Was 13 to 1 in All Cases

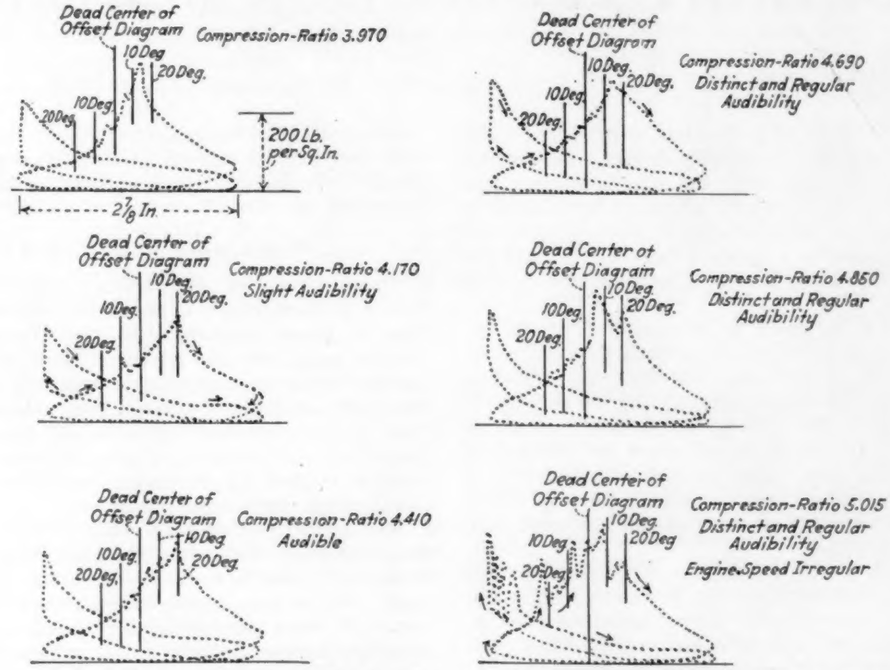


FIG. 21—DIAGRAMS FROM 2½ x 5-IN. VARIABLE-COMPRESSION ENGINE USING *X* FUEL
The Volumetric Compression-Ratio and the Character of the Detonation Are Indicated on Each Diagram. The Spark-Advance and the Air-to-Fuel Ratio Were the Same as in the Other Series of Tests, 20 Deg. and 13 to 1 Respectively

five different settings of this needle-valve, thus giving five different air-to-fuel ratios, against which can be plotted the various results for all the fuels and from which can be observed the various needle-valve settings that will give, for instance, an air-to-fuel ratio of 13 to 1.

Fig. 18 shows the behavior of seven different fuels when the compression-ratio of the engine was changed. The letter *A* on these curves indicates the compression-ratio at which the detonation or preignition first became audible. The break in the horsepower curve shows when detonation really gets in its work. When the lower horsepower values were obtained, conditions were unstable.

Fig. 19 shows the effect of changing the spark-advance on these same fuels, with the compression-ratio held at 4.55 to 1.00 for all fuels. These curves are similar to those shown in Fig. 18, the fuels showing substantially the same relative behavior. One of the fuels withstood a spark-advance of nearly 45 deg. before showing a material drop in power. The engine was operated at 1090 r.p.m. in all these tests. Air entered the carbureter at 100 deg. fahr. The cooling-water left the two parts of the head at from 170 to 180 deg. fahr.

Fig. 20 is necessarily somewhat blurred, as no attempt has been made to change the cards in any way. These diagrams show the series taken at the different compression-ratios marked with the "triangle" fuel shown in Figs. 18 and 19. Each card shows the conventional power-diagram with an offset diagram superimposed. The offset diagram is particularly interesting, since it affords an opportunity to examine the combustion process. The dead-center and the 10 and 20-deg. positions of the crankpin are indicated on each diagram. The increase in the combustion rate with increase in compression is apparent in these diagrams. The three diagrams in the top row show typical variations in combustion when only one spark-plug is used. The diagram at the left of the middle row shows more disturbance; whereas the central diagram of that row shows a rapid increase of pressure at 5 deg. before dead-center. The succeeding diagrams show the combustion line steeper and steeper, with, finally, a breakdown in conditions in the diagram in the lower right corner.

Fig. 21 shows similar diagrams for fuel *X*, the power curve of which is also shown on Figs. 18 and 19. These diagrams are similar to those obtained for the "triangle" fuel. These diagrams were obtained by a high-speed indicator that takes a composite diagram over about 800 cycles of the engine. The indicator is shown in Fig. 22 with the Crosby indicator in place, with an improved collecting manifold and four connecting-tubes.

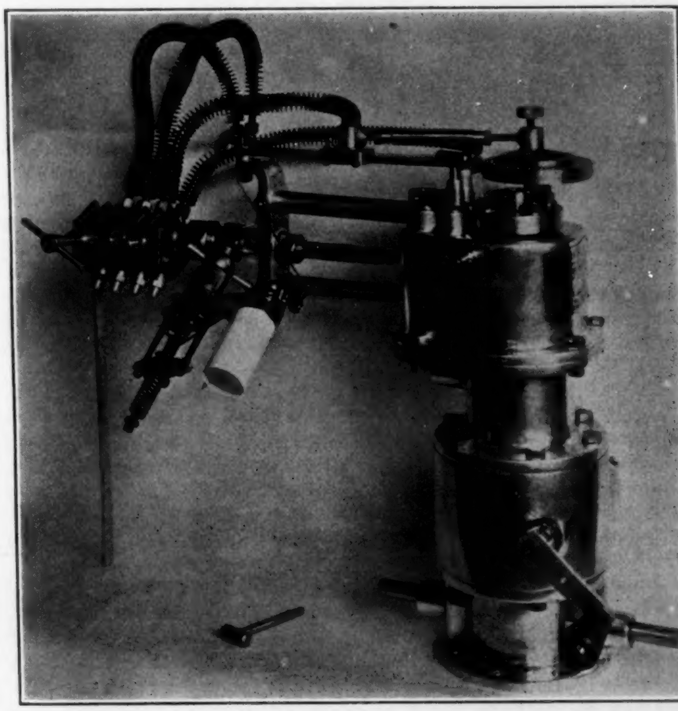


FIG. 22—HIGH-SPEED INDICATOR FOR MAKING COMPOSITE DIAGRAM
It is Shown with Crosby Indicator in Place, and with an Improved Collecting-Manifold and Four Connecting-Tubes, as It Would Be Used in a Four-Cylinder Engine

DETROIT PRODUCTION MEETING

(*Continued from p.* 550)

inventories in terms of days and this has a profound influence on the entire situation. It quickly brings out a condition of unbalanced inventory and, by specifying requirements by the number of days' supply of stores to be kept on hand, the inventory can be brought into balance quickly and the total inventory reduced in a marked degree. No calculation is needed to determine when additional material of a certain kind is needed.

A raw-material clerk is given a schedule of actual requirements and instructed to maintain a bank or surplus of, say, 10 days, in stores as an average. He then calls for shipments that will keep his inventory fluctuating from 5 to 15 days' supply on each item. Weekly reports show the condition of the inventory and it is simple to see when the number of "days on hand" is out of line. The number of days' supply to be carried increases when the production curve is rising and is cut to minimum when the production peak is approaching and a decline is expected.

Actual control of raw materials begins with the schedule clerk who controls shipments to meet the production demands. The quantity required is never more than 1 month's demand, unless especially authorized; and is always a quantity that makes an economical run for the supplier if possible.

A point to be emphasized, said the speaker, is that some one person must be delegated to control inventories, and it is most important that he be the proper person, with a definite goal set and with proper training.

In response to questions, Mr. Padgett explained that the 10-day basis of stores is only an average; that special steels, for example, are received in carload lots of 60 to 100 tons that may suffice for 3 months. With certain other materials the quantities carried may be 5, 10 or 20-day banks. In an industry where a multiplicity of small items are required the decision as to avoidance of less-than-carload shipments depends upon whether obsolescence and carrying charges would offset saving in shipping charges on 3 or 4-months' supply.

Raw-Materials Inspection in Telephone Business

L. I. Shaw, development engineer, Western Electric Co., in an address on the Quality Inspection of Raw Materials, at the Wednesday night session, gave a description of some inspection methods in the telephone manufacturing business and told the audience of some very close standards to which inspection is made at the plants of the company with which he is connected, the necessity for the standards and the methods of setting them up. The address was illustrated with lantern slides. The purpose of the standard and the inspection is to assure production of articles that will result in the greatest ultimate economy to the user. Methods of fixing standards for the control and maintenance of the quality of raw materials he divided into the empirical, or trial and error, method and the research and investigation method, and drew a contrast between them.

A first requisite to quality of raw material is the reliability of the supplier, and it is then necessary to have close cooperation between the supplier and the purchaser in the matter of specifications. It is desirable, whenever possible, Mr. Shaw pointed out, to use qualities of raw material having commercial tolerances, and he mentioned certain allowable tolerances and also told of requirements for which tests cannot be made.

The speaker then described specifically a variety of instruments for measuring length, thickness, weight, hardness, ductility, elasticity, electrical units, and time. Uses of thickness gages and optical magnification and the calibration of testing machines were explained. How to determine by statistical methods the amount of inspection necessary was described, and a considerable part of the address was devoted to ways of determining the choice of materials, such as ferrous and non-ferrous metals, textiles, paper, waxes and compounds, vulcanized fiber sheet, and slate. Availability and cost are, of course, primary factors in the choice of materials. In conclusion, Mr. Shaw spoke of the economic and technical benefits of control of quality.

Determining Periods for Gaging Gages

Commenting on Mr. Shaw's address, Mr. Coley, of the Leeds & Northrup Co., observed that an outstanding point is that a large company like the Western Electric Co., can obtain good results in inspection with low-paid employes under competent supervision, whereas a small company often must use engineers on inspection. Oscar Grothe called attention to the uncommon practice of the Western Electric Co. in gaging its inspection gages periodically and inquired what method is used to determine how often the gages should be checked by the master gages.

Mr. Shaw replied that when a new gage is started it is checked often and after that the experience with the gage determines the period, which varies for different kinds of gage. If a gage goes wrong between periods, other tests through which the material goes will soon show it. The first gage used on a material is the strictest one, and subsequent gages are very slightly less close to size. The demanding of materials to closer than commercial tolerances costs money, he pointed out, and should be avoided whenever possible.

CONTROLLING WORK IN PROCESS

Methods of Keeping Inventory of Materials in Process at the Minimum

The forenoon session on April 28, was devoted to consideration of planning and controlling work in process with a view to maintaining a low inventory of partly processed materials, which have a lower value than raw materials or finished products.

Even the banker looks with suspicion at a large process-inventory and, in arriving at a fair estimate of financial condition, will mark down the value of material in process more in proportion than either raw or finished materials, asserted Charles S. Craigmile, assistant general superintendent of the Belden Mfg. Co. He was speaking with especial reference to insulated wire, cable, cordage, and coils, production of which is of the progressive type. In these days of rapid changes in the design of all electrical equipment the planning and controlling of work in process, with the objects of fulfilling production schedules promptly and keeping the process inventory at the minimum, are extremely important.

The speaker outlined the method followed by the company with which he is connected in scheduling an order through the various departments and the control exercised over the order while the goods are in process. As a result of the control methods, each department knows just how fast to draw raw materials, and this enables the raw-material department to provide only enough material to maintain a steady flow of production. Each department is able to schedule its work in accordance with the delivery of process material from other departments, and "work-ahead" sheets sent to the production department every week by the manufacturing departments prevent over-scheduling, which is a common cause of excess process-inventory. The sales department is kept in constant touch with the condition in each department and can push the sale of items needed to fill up manufacturing schedules and shut off sales for departments that are producing at capacity. Each department is also able to plan the probable increase or reduction of the working force for several weeks in advance.

As a general check the company has, on the basis of its experience, developed figures that indicate approximately how large the process inventory should be for various stages

of activity, and is now working out charts which show the dollar value the process inventory should have as the maximum for definite amounts of productive labor. These will give immediate warning when the process inventory is becoming too large.

It has been found, concluded the speaker, that in addition to these definite methods of control, perhaps the most effective means of all lies in education of the organization in the basic reasons for the necessity of such control. At foremen's meetings there is frank talk of actual cost figures and of increased profit due to improved turnover. This policy has helped the foremen and their assistants to control the work in their departments better and made them want to control it.

Wiping Out Excess Process-Inventory

How is an inflated process-inventory wiped out? asked a discusser. Mr. Craigmile replied that the production department applies the production schedule against the work of the machines and the operators, and the department heads must work-out the situation in their departments. If more material or labor is put into the process than the schedule calls for, the inventory will show the fact. The foreman is aware of this and knows that nothing can be hidden. A blue requisition-sheet used for excess orders serves as a warning flag. The payroll exposes excess labor cost. At the end of the year the excess inventory is taken as a loss and comes out of the year's operation. A recurrence is corrected by an immediate checking of the excess. When a blue excess-requisition comes through, an analysis of the product is made, and it sometimes shows that a certain material is not of proper quality. This condition is minimized by putting shop orders through in small lots.

Mr. Norton remarked that Fairbanks, Morse & Co., charge excess process-cost currently to profit and loss.

Another discusser stated that his company places the budget and actual cost figures before its superintendents and foremen so that they know what is going on and why. This gives them a liberal training and results in a healthy condition. The employes are virtual partners in the business; they are provided with all needed facilities and taken into the confidence of the executives, with the result that their intelligent cooperation is secured.

Little difficulty had been encountered by his company, said another speaker, in setting standard costs on every item of thousands made. When a new article is brought out, the original standard is set up on the basis of time studies. Standards are reset annually, based on records of variations of actual cost of different operations from the existing standards.

Labor Hours Budgeted by Work Scheduled

The scheduling or budgeting of labor hours, both direct and indirect, according to the amount of work scheduled for a given period is a detail of manufacturing control that has had scant attention, asserted J. D. Towne, industrial engineer. This is of even more importance, however, than production schedules.

Speaking of the methods followed by the Dayton Steel Foundry Co., whose product is entirely cast-steel wheels for motor-trucks, of which 3000 varieties of pattern have been made, he said that more than 90 per cent of the hours worked have been time-studied; standard times have been set on the job, whether of direct or indirect labor; and a wage incentive in the form of a bonus is offered to each worker for proper accomplishment of his individual duty within the time specified. From these standards a "man-load" budget is developed for every individual department; that is, from actual time-studies the number of hours necessary to be worked in each department for any percentage of production capacity is calculated and shown upon master sheets. These sheets, which include every department and are based on a period of 4 weeks, show the number of wheels to be produced and the aggregate weight of the production, pounds per man per day in summer and winter, and the total man-days and total hours in summer and winter.

The degree of productivity, or percentage of capacity, for the coming week is taken directly from the weekly schedule issued by the production department, then the number of hours required in each department for this production is calculated from the master man-load budget, and a memorandum is handed to each department head and superintendent giving the number of hours his department is expected to work during the succeeding week.

Real control of the situation comes from the follow-up. The comptroller receives at the beginning of each week a man-load control sheet for both the foundry and the machine-shop. This sheet shows the number of budgeted hours in each department for the week and in parallel columns the actual hours worked daily. The last column shows the total actual hours for the week, which can be compared easily with the budgeted hours. A short study of the figures shows the departments that have worked too many hours and enables the comptroller to investigate discrepancies while the circumstances and conditions are fresh in the minds of all concerned.

This system, said Mr. Towne, will bring under absolute control the item of expense that represents by far the largest amount of money in most industries. At the same time each department will have two definite goals that it must attain or else must explain satisfactorily the cause of failure. These are (*a*) a given production and (*b*) not more than a stated number of hours of work.

A manufacturing-expense budget is also given to the shop as a further control over work in process. This is drawn up in a way similar to the man-load budget and covers 45 to 50 items of expense, each apportioned in standard amounts for each 10-per cent increase in manufacturing production from 0 to 100 per cent of capacity.

While the fundamental idea of developing definite control over all manufacturing conditions no doubt is the selfish desire to lower costs, increase production and increase net profits, said Mr. Towne, such control also brings real benefits to customers. Quantity and quality specifications can be more easily realized, rush orders and special delivery dates can be promised with accuracy, and ultimately the sales prices are lowered.

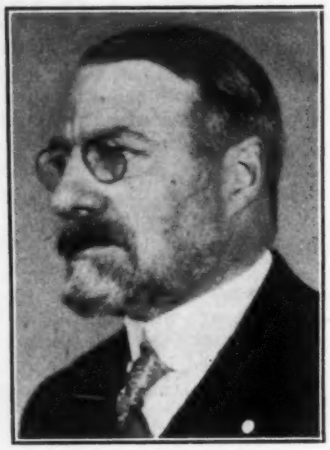
Discussion developed the further facts that if a department carries its load with fewer man-hours than the schedule calls for, each foreman is paid a bonus for the decrease in labor cost; time-study is the most important phase of present industry; the optima of efficiency lie between the increments of 10 per cent in productivity and actual work is scheduled in accordance with these optima; and it has been found that the most efficient production is at about 80 per cent of maximum capacity.

ACCIDENT AND PRODUCTION RATIOS

Man-Hour Rate Used as Yardstick—Production Control System of a Small Company

At the afternoon session W. W. Nichols, vice-president of D. P. Brown & Co., presented for L. P. Alford, editor of *Manufacturing Industries*, who was unavoidably absent, a summary of a report of the Committee of the American Engineering Council on the Relation of Safety to Production. The full report is to be published in about a month and will contain about 400 pp. More than 30 lantern slides of charts were shown with the summary.

The report reveals some remarkable findings by the Committee in different major industries, including a positive relation between the rate of production per man-hour and the rate and severity of accidents, and in many cases an increase of the rate of production accompanied by a decrease in rate and severity of accidents over a period of 5 years. In the automobile industry, however, the increase in production has been accompanied by a greater increase in accident frequency. In the operations of a large taxicab company, on the contrary, an increase in work on the man-hour basis has been accompanied by a decrease in accidents amounting to three or four times the percentage of increase in work.



J. D. Towne W. W. Nichols
Mr. Towne Spoke on the Importance of Budgeting Labor Hours and Mr. Nichols Was Chairman of One of the Sessions

Discussion brought out that a yardstick had been found by the Committee for measuring the ratio of accidents on the man-hour basis that can be applied everywhere and make comparisons possible; the accident record in small plants is disgraceful by comparison with that in large plants; the offering of bonuses to speed-up production tends to decrease the accident rate rather than to increase it; uncompensatable losses due to accident are four times as large as compensatable losses, due to loss of time by workers not involved in the accidents; the accident rate goes up as new employes are taken on when production is increased, and the great reduction in accident rate by the telephone companies is attributed to training of the foremen and placing on them the responsibility for avoiding accindents to the workers.

Production Balanced with Sales

A system used by a small company for governing production with relation to sales was explained in detail with charts by W. A. Rowe, of the Black & Decker Mfg. Co. Sales estimates and production schedules are revised monthly and a manufacturing control chart provides for regulation of production. The governing factor on this sheet is the weekly sales. Another sheet shows actual weekly production. The company works backward from shipping dates instead of forward from dates of receipt of materials, and thus determines when materials must be ordered. This also controls the inventory of materials in process and in assembly.

Production schedules are laid out on a planning board, and a chart shows the days required to complete each operation and determines when to start the various operations. Each department operates on a budget, and costs of every operation are ascertained upon its completion.

All executives meet weekly and tell of any conditions in their departments that may delay production. These meetings are very valuable, said Mr. Rowe, because they give all department heads a full knowledge of conditions. All have access to detail costs on each article and try to reduce these costs. Moreover, the sales department drives the production department at times, and at other times the situation is reversed. The sale price is made first and production cost is determined afterward. The company never carries in process more than 3200 units on unfilled orders, although it often has 5000 units on hand, as 60 per cent of its sales come in the first 6 months of the year, and some standard articles are made for stock in the second 6 months.

A great deal of interest was taken by his hearers in Mr. Rowe's exposition of the system and there was considerable discussion of details, which brought out that workers are hired on the hour basis and paid bonuses only for regularity in reporting for work, a certain amount of equipment must be kept idle at periods to take care of new or special jobs and the system of control is used effectively in three plants, one of which is in Maryland, another in Indiana and a third in Canada.

HUNT PRESIDES AT DINNER

Russia's Industrial Development and Engineers' Part in Our Prosperity Pictured

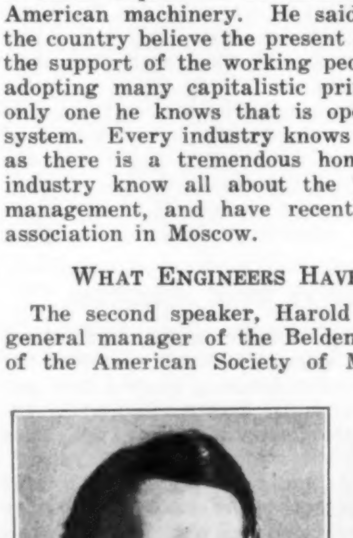
Industrial Conditions in Russia and Imagine Production Without Engineering were the subjects of addresses given at an informal dinner held on the evening of April 28. J. H. Hunt, of the Chevrolet Motor Co. and president of the Society, presided and in his introductory remarks said that it was an encouraging sign that management is recognizing the engineers and trying to educate them; they need to know more about financial and economic conditions. He was glad, he said, to see the joint meeting of the management association with the engineering societies.

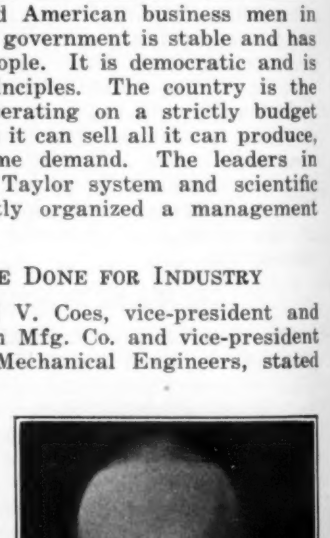
Russian industrial production is now up to 90 per cent of pre-war production and will be greater by next year, said Frank J. Tone, president of the Carborundum Co., who recently returned from a visit to the country of the Muskovites. He was especially impressed, he said, with the eagerness of the workers to learn the most modern methods and acquire technical knowledge. It is not true that all industry has been nationalized and demoralized. The large industries have been taken over and some are badly managed but others are well managed, are up to American standards and would be a credit to any country. There is only one automobile factory, which was started from nothing 6 years ago and now employs 2400 workers, makes all its parts for passenger-cars and trucks and its own dies and castings and has an electric furnace. It conducts an apprentice school with 60 boys operating lathes and other machines, and among the workers are several young Russian-Americans who formerly worked in Detroit automobile plants.

Russia is marvelously rich in natural resources, continued the speaker, and is discovering new resources and developing some of its potential 30,000,000 water horsepower. It will some day be the richest Eastern European country but it needs capital to reconstruct its industries and wants American machinery. He said American business men in the country believe the present government is stable and has the support of the working people. It is democratic and is adopting many capitalistic principles. The country is the only one he knows that is operating on a strictly budget system. Every industry knows it can sell all it can produce, as there is a tremendous home demand. The leaders in industry know all about the Taylor system and scientific management, and have recently organized a management association in Moscow.

What Engineers Have Done for Industry

The second speaker, Harold V. Coes, vice-president and general manager of the Belden Mfg. Co. and vice-president of the American Society of Mechanical Engineers, stated





J. H. Hunt F. J. Tone
The Toastmaster (Left) and the Principal Speaker (Right) at the Dinner

that American industry has been brought to its present state by cooperation of science, engineering and scientific management, He reviewed briefly the development of the factory system through several centuries from the guild and cottage system to the present system and said that the last development was due to invention of machinery and of water, steam and electric power. This released a tremendous volume of man-power. The engineer transferred human skill to machines. The financier then came into the picture for the building of large factories and an industrial revolution began. Transportation facilities then freed the factories from close association with sources of raw materials, with the results of the development of more power, subdivision of labor, and mass production.

Imagine, therefore, what is due to engineering, financing, management and cooperation, said Mr. Coes. As Napoleon is credited with having said, wise direction and strategy are better than great numbers of men. Through the mechanism of industry our National wealth has been increased enormously. Each person in the United States has 35 invisible slaves working for him. We are deeply indebted to the engineer for this and the prosperity it has brought. No man working unaided can do enough work to give himself comfort. The real task of the future, the speaker said in conclusion, is to balance the factors of management in industry; we must keep our minds open and our organizations flexible so as to be adaptable to rapidly changing conditions.

TRAINING PAYS FOR ITSELF

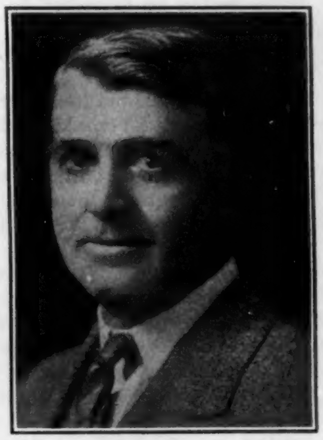
Apprentice System That Increased Production—Avoiding Expense in Design Changes

Much grief and loss of time, money and material would be avoided if psychological and other tests were applied to applicants before engaging new employes, asserted Walter S. Berry, director of training for the Scovill Mfg. Co., at the forenoon session on April 29. Before deciding upon the training system to be adopted, the company investigated the value of employment tests in making a selection of persons to be trained. Apprentices were studied first and it was found that 18 per cent of the boys were too slow or could not learn and, since eliminating these by the tests, not one of the rest has been incapable of learning to do the work.

Then old employes in the toolroom were investigated. The foreman selected 80 toolmakers to be trained in simple mathematics. After 2 months only 17 remained who were able to learn. Psychology tests were given to the 17 and only 11 were found fully capable of mastering the mathematics. Twenty men of the original 80 were shown by the tests to be of such low mentality that they could not even go through the public school course, said the speaker. The 17 who passed the tests were given the training they needed and most of them have had definite promotion.

The method that proved successful was the taking of apprentices who were scattered through the various departments in the plant and segregating them in a room by themselves, where they are organized into production groups by classes of work. The training course extends over 4 years and old and new apprentices work beside each other. This affords an incentive to the beginners, who see that it is possible to acquire accuracy and speed and therefore gain confidence. It has been found that on certain lines of work as much production can be got from the apprentices as from the older workers and at much lower cost, although this is not true of all kinds of work. The boys are paid what they earn from their first hour on a machine and are advanced as they become qualified. Thus the training course pays for itself. It has also been found that apprentices can work to close micrometer limits after a period of training. Full explanations of the way to perform the work are given and the boys are studied to determine the kind of work for which each is best fitted.

An important phase of the work was the training of superintendents and foremen in the organization of work



WALTER S. BERRY ALBERT SOBEY

Mr. Berry in His Paper Described an Apprenticeship System That Increased Production; in His Discussion of the Paper Mr. Sobey Emphasized the Importance of Organizing Training To Eliminate Waste

in their departments and in teaching the workers under them. In any training program to reduce cost of production it is necessary, said Mr. Berry, to give training in teaching to superintendents and foremen.

ORGANIZE TRAINING TO ELIMINATE WASTE

Albert Sobey, director of the General Motors Institute of Technology, in opening the discussion, said that training should be organized with the intent to reduce cost of production and eliminate waste due to spoilage. He cited instances in the automotive industry in which reduction of spoilage by from 6 to 20 per cent would have enabled the departments to make from 20,000 to 70,000 more parts in 1 year with no increase in the labor force. He also spoke of the importance of reduction in labor turnover as a result of efficient training. Although large groups of men seeking employment are gathered daily outside of Detroit employment offices, a constant demand exists for skilled workers who are not to be found in these groups.

W. W. Nichols, vice-president of D. P. Brown & Co., suggested that prospective employes be given a test by handing them blueprints of machines they would be expected to work on and then quizzed regarding their manipulation. This would save time, material and machine damage by eliminating those who claim to be competent but who do not understand the machines.

CONTROLLING COST OF CHANGE IN DESIGN

The time to begin controlling avoidable expenditures during a change of design is beforehand, asserted E. E. Vender, manager of the systems staff of Ernst & Ernst, in an address on this subject. Control of avoidable expenditures resolves itself into a matter largely of comparing daily and weekly reports with a predetermined chart of procedure, ascertaining the reason for any variance and exercising resourcefulness. If the extra cost of making a change of design effective in 30 days rather than 60 days is not warranted by the advantages to be gained, the extra cost is avoidable waste.

All important changes of design should, before adoption, be considered by a committee representing the sales, manufacturing, engineering, accounting, purchasing, and planning departments. When a change is contemplated the engineering department should issue preliminary notices so that material and purchase records will be brought uptodate. A second notice to all departments concerned should call for a prompt assembling of sufficient data on existing conditions in each department for an intelligent preliminary conference. The first step in further consideration of the proposed change is preparation of estimates to show the cost of putting the new design into production within different time periods, and if the change is adopted the department

heads would be expected to keep their costs within the estimates.

In automobile plants charts are maintained that show for each unit of the car the normal minimum time in which a change can be made effective. These reflect the normal time required for making drawings, model, test, tools, procuring materials, processing, and so forth.

The costs of getting a new design into production are divided into equipment costs and manufacturing costs. Under the former come (*a*) new dies, patterns and tools and (*b*) loss through disposition of present equipment. Under the latter come (*a*) obsolescence of materials, (*b*) increase or decrease in normal cost of new parts, (*c*) factory expenses in excess of normal, (*d*) additional costs if the change is rushed, (*e*) cost of replacements and free service, and (*f*) excess of direct-labor cost during the time of developing standards on the new product.

Capacity of the supplier to furnish a specified material in desired quantity at the time the change is planned to go into effect is important.

Companies operating under a budget-control system usually make a special appropriation for the change and classify this as part of the general expense budget.

The importance of planning in advance every step of the work cannot be over-estimated. All department heads must prepare time schedules covering every item required and these schedules must be coordinated. During the course of the change, daily and weekly reports of progress are required. Time schedules and cost estimates are the standards by which the successive steps in actual accomplishment are measured.

The possibility of incurring really avoidable expenditures is minimized if responsibilities are clearly defined and placed upon proper individuals who will maintain supervision and checking all along the line. The committee in charge of change of design is responsible to the works manager, and the purchasing and engineering departments must follow up the suppliers.

Avoidable expenses to be guarded against are (*a*) excessive overtime, (*b*) bringing in materials expensively, (*c*) rushed requirements, (*d*) shutdowns for equipment changes, (*e*) delays that affect other departments, (*f*) delays resulting in unfilled orders and loss of sales, and (*g*) errors in engineering specifications, equipment plans and purchasing instructions.

WHEN OUTPUT GOES UP OR DOWN

Elements of Avoidable Manufacturing Expenditures That Are Subject to Control

Control of avoidable manufacturing expenditures with variable output does not infer that such expenditures can be maintained at a standard uniform level, said H. G. Perkins, industrial engineer of the Chrysler Corporation, at the final session. Unit expenditures will fluctuate with fluctuating production because of the influence of fixed charges alone, and other outlays classed as controllable are of such a semi-permanent character as to offer stubborn resistance to change.

The universal use of incentive wage-payment plans automatically regulates the volume of labor to the rate of output, and where this plan is not used supervision is relied upon to accomplish this result. Increase or decrease of output has little or no influence on unit material price, which is established by the purchasing division and is not subject to change except when quantities drop to the minimum below which a price adjustment is demanded by the suppliers. Likewise the volume of vendor commitments is determined largely by market conditions and the purchasing policy.

The regulation of expenditures for incoming materials and reduction of the materials inventory to the minimum consistent with the volume of output is so vital to successful operation that elaborate procedure is justified and highly capable personnel is essential. Starting with the element of time required by suppliers to receive and fabricate rough material, through the stages of movement in transit, receipt and inspection, fabrication and assembly, to final test and shipment, an experienced and intelligent guiding hand is indispensable. It is difficult also to conceive of satisfactory results unless capable supervision is supported by data that indicates accurately the status of every item included in the bill of material.

Budget Control Lays Somber Specter

Mr. Perkins next referred to the element of burden as a somber specter that submits least readily to regulation and causes management the greatest concern. Undoubtedly the most valuable ways to regulate burden, he said, are of such a character that they answer the questions, Where? and How much? For this purpose nothing is so effective as predetermination of costs, otherwise known as budget control. It is unquestionable that intelligent budget quotas stimulate department heads to closer and keener challenge of the necessity for every cash outlay, and they give to management a very definite means for intelligent adjustment of current-expenditure rates.

Although budget control is a comparatively recent innovation, it is even now clear, continued Mr. Perkins, that certain principles exist that must be recognized as the foundation of successful operation. The installation of such control will not, of itself, regulate expenditures; it can serve only as a tool of management and an indicator of desired results, and its effectiveness is dependent upon the hand that regulates it. Of first importance is the character of the contact between the control unit and the individual held responsible for outlay. This relationship is best realized. perhaps, when the responsible individual has a voice in the deliberations that determine the budget quotas, and the quotas must be sufficiently rigid to stimulate vigilance and challenge every outlay, yet sufficiently reasonable to command respect. And we can assume that best results will be obtained if quotas are issued for the immediate current period rather than for an indefinite extended period.

Undoubtedly the most important part of budget-control procedure has to do with enforcement and the most important weapon in budget enforcement is the setting of intelligent quotas, said Mr. Perkins. If there is cooperation in setting the quotas there will be cooperation of effort in not exceeding them. Department heads are not of a type to be severely subjected to the lash but are capable of judging their ability to meet budget requirements. The biggest step toward fulfillment will be made if quotas are given them with the understanding that they are to serve as a guide in limiting outlay. The next step is to provide the responsible department-head with prompt reports showing the comparison of actual expenditures with the budget quotas. Armed with these data, he can make an itemized study and apply pressure to the localized excesses that are revealed.

Since good management is consciously or unconsciously making use of the elements of budget control, concluded the speaker, consideration may well be given to the possibility of increasing the effectiveness of these tactics by elevating them to a recognized position and giving them the dignity of a formal title.

ACTIVITIES OF THE SECTIONS

(*Continued from p. 565*)

of curvature of the curb at corners, safety islands and center installations of traffic signals, parking, obstructions during building construction, and other like constrictions of the road width, cause serious obstacles to the free movement of traffic.

After discussing briefly the subject of parking restrictions, Mr. Robb mentioned that the "per lane capacity" of a street is a function of the vehicle speed and of the spacing between vehicles. But he said that the spacing is proportional to the speed and increases proportionately greater than the speed above a certain point so that excessively high speeds do not succeed in passing a large number of vehicles. He then went on to discuss synchronized and other forms of traffic control systems in use or projected for Chicago and other cities, commenting upon their main features of advantage or disadvantage. Speaking with regard to the differences between the synchronized, the isolated and the progressive types of control, Mr. Robb mentioned that one authority uses various names for the last mentioned types, such as, reciprocal, staggered, cascade, ripple, shower, and wave methods, as well as the terms platoon and partial platoon. The last two distinctions were suggested because the vehicles are thereby separated into platoons or trains and proceed along their course in groups.

In the discussion following the presentation of the paper, Harvey D. Wood, safety director of the Yellow Cab Co., Chicago, contributed an interesting account of the experiences of the drivers of this company in relation to the operation of the present traffic-control system. He said there is unnecessary confusion owing to the use of the red, green and amber-light signals that could be eliminated by abandoning the use of the amber light and relying on the use of two red signals before a change in vehicle movement, to stop and clear the moving line before the standing line started.

He commended the system of progressive lighting now in vogue on main arteries and believes that drivers will soon learn that spurts of speed only bring them to a red-light stop where the time gained is lost. He told of an experiment in which two taxicabs started out to reach a country club 8 miles away. They were driven over the same route, one observing all regulations and the other breaking 38 of them, with the permission of the authorities. The conservative driver did not exceed 25 m.p.h. The reckless driver touched 45 m.p.h., but he beat his law-abiding opponent by only 4 min., as the signals aided a steady 25-m.p.h. speed.

Mr. Wood stated that his company's taxicabs were not generally equipped with speedometers, but the drivers had no trouble in maintaining good speed without causing accidents. Conservative driving is the answer. The company employs inspector drivers who report any reckless driving on the part of the other taxicab drivers. The inspector-driven cabs are equipped with speedometers.

Mr. Wood said that creosoted wood-block pavements cause many collisions owing to their being very slippery when wet. This should be brought to the attention of the authorities by organized bodies having influence in bringing about abandonment of this type of pavement.

OILS AND LUBRICATION

Informative and Interesting Addresses at Big Southern California Meeting

Pistons in a four-cylinder 5-ton truck travel 4 miles vertically for every forward mile of travel of the truck in high gear, and the piston-wall area of the engine is more than 300 sq. in., Lawrence T. Wagner, lubricating engineer for the Standard Oil Co. of California, told members and guests of the Southern California Section at the Section's monthly meeting at the City Club in Los Angeles on April 8. To carry the mathematics a little further than Mr. Wagner did for the purpose of indicating the magnitude of friction to be overcome by lubrication, a 5x6-in. four-cylinder engine has a swept cylinder-wall surface of approximately 90 sq. in. per piston stroke, eight piston strokes per revolution, 4 ft. of piston travel per revolution, and sweeps nearly 25,000 sq. ft. of cylinder-wall per mile of travel. Obviously, the effective lubrication of such an area every 4 min., at a rate of travel of 15 m.p.h., is a task of some magnitude, and accounts for the great interest in the subject of oils and lubrication that resulted in 145 dinner reservations for the meeting and an even larger attendance at the technical session afterward.

Following delivery of the Wagner paper, T. F. Ott, lubricating technologist of the Union Oil Co., of Los Angeles, told of the difference in characteristics of lubricating-oil made from paraffin-base crude oils, Pacific Coast asphalt-base crudes and Mid-Continent mixed-base crudes. Discussion

SCHEDULE OF SECTIONS MEETINGS

MAY

3—BUFFALO—Worm-Gear Bronze—T. W. H. Jeacock

4—MILWAUKEE—Illuminating Engineering with Special Reference to Automobile Headlighting—W. D'Arcy Ryan

5—DETROIT—Contest Meeting—Four papers on Car of 1937

10—CHICAGO—Interesting Design of High-Speed Two-Stroke-Cycle Engine—Lee W. Oldfield

PENNSYLVANIA—The Armstrong Seadrome—Edward R. Armstrong. Crop Dusting by Airplane—Edgar N. Gott. Local Flying—Lieut. J. G. Ray. Aerial Photography—E. H. Cahill. Airport and Airway Lighting for Night Flying—E. A. Leinroth

12—INDIANA—Relation of Universities to Automotive Manufacturers—J. H. Hunt, Dean A. A. Potter, Prof. H. A. Huebotter, Prof. G. A. Young, and F. F. Chandler

NORTHERN CALIFORNIA—Short Haul Trucks—W. W. MacDonald. Paving and Its Relation to Motor Transportation in the City—A. J. Eddy

13—SOUTHERN CALIFORNIA—Tires—Alvin N. Day

14—CLEVELAND—Trip to Columbus as guests of Ohio State University Student Branch. Talks by Dean Hitchcock, Prof. John Younger, J. H. Hunt, and F. F. Chandler

17—S.A.E. CLUB OF COLORADO—Welding and Liquid Oxygen—Chester Mott

19—METROPOLITAN—Motor Equipment—Donald Blanchard

was participated in by representatives of other oil companies, T. A. Fitch, of the City of Los Angeles testing laboratory, and others.

In the short business session with which Chairman Eugene Power opened the meeting, attention was directed to the appointment of E. C. Wood, of San Francisco, as Pacific Coast chairman of the Operation and Maintenance Committee of the Society and the increased attention to be given by the Society and THE JOURNAL to this phase of automotive engineering, which is of most importance to Pacific Coast members.

The Chairman stated that the membership of the Section almost doubled in the last year and that the Southern California Section now has 134 members, while the Northern California Section has 127 and has placed a wager that it will surpass its southern sister Section in membership.

Eustace B. Moore, of the Los Angeles Automotive Works, was elected to represent the Southern California Section on the Nominating Committee for election of Society officers for 1928, and F. C. Patton was elected alternate. The meeting voted to endorse the recommendation by J. F. Winchester for amendment of the Society Constitution to abolish the office of Second Vice-President representing stationary internal-combustion engineering and create the office of Second Vice-President representing operation and maintenance engineering.

How To Maintain Good Lubrication

After discussing the variables in engine operation that directly affect cylinder lubrication, Mr. Wagner, in his paper, made a number of practical suggestions to operators for obtaining the best possible results from automotive equipment now in use. He listed the more important variables as

(1) Viscosity of the lubricating-oil
(2) Accumulation of solid impurities inside the engine
(3) Volatility of the fuel used
(4) Cylinder-wall temperature
(5) Engine-speed
(6) Intake-manifold depression
(7) Mechanical condition of the engine

The way in which each of these affects lubrication was explained. It is desirable to operate engines at comparatively high temperatures to reduce the fluid friction in the oil, he said, but the oil should have sufficient body at these temperatures to prevent metallic contact between the pistons and the cylinder-walls and to preserve an efficient piston-ring seal. The maximum allowable viscosity is determined by the piston design and the clearance between the pistons and the cylinder-walls. Excessive cylinder wear, scoring of the cylinders and seizure of the pistons are seldom the fault of the oil, and the cause should be looked for elsewhere. When piston-rings and ring grooves become worn badly heavier oil will assist in offsetting this, but the use of an extremely heavy oil may do more harm than good, and if poor piston-seal develops it is better to correct the mechanical condition.

It is advisable, said Mr. Wagner, to use an oil that will form the minimum amount of carbon and from which the carbon formed is of a nature that will not injure the bearing-surfaces. Air-cleaners are effective and beneficial to the extent that they prevent entrance into the engine of injurious solids, and their use should be encouraged. When wearing-in a new engine, considerable metal in small particles is removed from the cylinder-walls and pistons, hence frequent renewals of the crankcase oil should be made. Oil-filtering devices on automotive engines are of benefit in proportion to the percentage of impurities they remove, but too much reliance should not be placed upon them, as it is possible, according to the speaker, for solids to accumulate in an engine equipped with such a device.

Fuel of sufficient volatility to gasify completely in the combustion-chamber should be used, to reduce dilution of the lubricating-oil and avoid impairing of the piston seal. When warming-up cold engines after starting, they should be run at low speed until heated, because the oil is more viscous and does not immediately lubricate the cylinder-walls in force-feed engines and, moreover, water condensed in the engine may have rusted the walls.

Special piston-rings, bleeding of the pistons and measures of a similar nature intended to regulate the quantity of oil delivered to the cylinder-walls under varying operating conditions are beneficial, asserted the speaker, when they succeed in controlling the supply of oil that passes to the upper walls provided they do not rob them of the necessary supply. Reduction of oil-feed to the cylinders, however, is often carried too far in an effort to decrease the oil consumption per mile of operation. Too much oil is better than not enough.

Gas pressures above and below the pistons have an important effect on the upward flow of oil to the piston-rings. When operating with a small throttle-opening, as in idling and running under light engine-load, the intake-manifold depression is considerable and little compression pressure is developed. Both combustion and exhaust pressures are also lower and the oil has a tendency to accumulate above the pistons. Operation at full throttle-opening has the converse effect, and it is advisable, when it is necessary to maintain prolonged operation with full-throttle, to close the throttle temporarily as opportunity permits.

Oil consumption increases gradually with age and use of a vehicle. The rate of consumption is fixed chiefly by the piston-rings and, as these wear more rapidly than other bearing parts, it is frequently advisable to renew the rings when oil consumption increases unduly. Wear of the ring-grooves is more important than wear of the face of the rings, as motion of the rings in the grooves causes consumption to increase rapidly.

With splash-feed lubrication, said Mr. Wagner, care must be used, when taking down the crankcase, to guard against any changes or damage that will change the oil level in the dip troughs. A comparatively small variation in the amount of dip will greatly vary the quantity of oil thrown to the cylinders. With force-feed lubrication, if the clearance in one connecting-rod bearing becomes greater than that in others, more oil will be delivered to that cylinder and less to the others. Therefore, when any work is done on connecting-rod bearings, it is necessary to make sure that all the bearings have the same amount of clearance.

The Evaluation of Lubricating-Oils

As much as 30 to 40 per cent of the energy from the fuel is lost through friction in the internal-combustion engine, which shows how important the prevention of friction is, asserted Mr. Ott in his address. He divided friction into fluid friction, due to movement of the molecules within the oil film, and solid friction, or movement of two metal surfaces upon each other when not completely separated by an oil film. Solid friction may be affected by speed of movement, pressure on the metals and viscosity of the oil. As investigation has shown that oils of the same viscosity have the same coefficient of friction, it makes no difference from what crude petroleum the lubricating-oil is produced so long as the metal surfaces are kept apart, but the factors involved in solid friction do make a difference from what crude the oil is made.

All lubricating-oils are made from crude oil obtained in the United States, said Mr. Ott. Viscosity is not the only characteristic by which to judge an oil; otherwise molasses might be chosen. The oil must spread over the surface of the metal; oils from different sources spread differently and the edge of a drop forms different angles with the metal on which it is placed. This fact is thought to be related to chemically active materials that occur in some oils.

Crude oils of the United States may be divided roughly into (*a*) paraffin-base, or Eastern, oils; (*b*) naphthene-base or Western, oils, and (*c*) Mixed-base, or Mid-Continent, oils. To combat a common impression, the speaker explained that all crudes are composed of hydrogen and carbon united in varying proportions; that the Eastern crudes have a predominance of paraffin hydrocarbons while the naphthene, or so-called asphalt-base, crudes have twice as many hydrogen as carbon atoms, but that, whereas lubricating-oils made

from Eastern crudes contain paraffin, those made from Western crudes do not contain asphalt, because the asphalt is all left behind in the distillation process. All lubricating-oils must contain carbon, however, and Conradson tests prove that oils made from the Eastern paraffin-base crudes deposit from two to five times as much carbon as Western naphthene-base oils. Moreover, the deposit from the former is hard and flinty, whereas that from the latter is soft and fluffy and most of it blows out of the cylinders with the exhaust gases.

Oils from Western Crudes Declared Superior

Mr. Ott made it plain that, notwithstanding the inherent differences in oils from the various crude petroleums, any lubricating-oil made by a reputable company is good and is safe to use, although, if the fine points of distinction are considered, the fact that an oil from a Western base is superior to one from an Eastern base cannot be refuted. The two types have different physical and chemical properties. The former is essentially lighter in gravity, but this means nothing except that the purchaser receives more pounds per gallon in the Western oil.

Flash and fire-tests, in which a small quantity of oil is heated in a small cup over a gas flame until a flash occurs and then goes out and with further heating the oil burns continuously, show that Eastern oils flash and burn at higher temperatures than Western oils. The difference between the flash and fire temperatures in oils of the same grade, however, the speaker said, is never greater than 50 deg. fahr. In any case the flash-point is higher than the temperature of the cylinder-walls of an internal-combustion engine, which is not above 275 deg. fahr., if the engine-cooling system is in proper condition. The flash-point of the oil in the crankcase is lowered, however, by dilution with gasoline from the cylinders, which ranges from nil to as much as 40 per cent. A small percentage of gasoline often reduces the flash-point below 200 deg. But the flash-point is of no importance so far as functioning of the oil as a lubricant is concerned; whatever quantity of oil passes beyond the pistons into the combustion-chamber is consumed, whether the flash-point is 400 or 600 deg.

Viscosity Not an Indication of Quality

The viscosity test is a grading test but does not indicate quality nor definitely measure the lubricating value of an oil. Light, medium and heavy oils are tested for viscosity to make sure that they are right as to grade. Viscosity is important as it relates solely to fluid friction within the oil itself. Eastern oils have a somewhat flatter viscosity-curve than do Western oils; that is, of two oils having identical viscosity at 100 deg. fahr. the Eastern oil, when heated to 210 deg., has greater viscosity than the Western oil at the same temperature. But at temperatures as high as 300 deg. all grades of oil, whether light, medium or heavy, have virtually the same viscosity. The Eastern oils decrease in viscosity, or "thin out," less upon heating than the Western oils, and, conversely, the latter increase in viscosity, or thicken, more than the former with cooling after they are heated.

It is a question for argument, said Mr. Ott, whether it is important that, after an engine is stopped, the hot thin oil tends to drain from the cylinder-walls or that, as the engine cools, the oil thickens and gives a better piston seal for starting the next day.

In the ice-and-salt cold-test Eastern, or paraffin, oils solidify or cease to flow at temperatures of about 32 deg. fahr., whereas the Western, or naphthene, oils can be chilled to below zero and still will flow. This fluidity at below-freezing temperatures is important in cold weather.

Color of an oil cannot have any reference to its lubricating value except as an indication of its ability to spread over the surface of a metal. As he stated previously, Mr. Ott said that this ability depends upon the content of chemically active hydrocarbons.

Chemically Active Oils Are Oilier

In England, where the theory that germs are responsible for this characteristic, fatty acids are added to oils to decrease their coefficient of friction. Dr. Mayberry, of the Case School of Applied Science, has asserted that all lubricating-oils owe their lubricating value chiefly to the presence of unsaturated, or chemically active, hydrocarbons, according to the speaker, who also said that a test has shown that unsaturated hydrocarbons develop only one-half the friction developed by saturated, or chemically inactive, hydrocarbons. As a class, Western oils contain more of the unsaturated hydrocarbons than do Eastern oils. Many authorities agree that a chemically active oil is best for lubrication. If too much of the chemically active content is removed in refining and lightening the color of the oil, its lubricating value is impaired. White oils have been found unsuitable for lubricating internal-combustion engines. The refiners do not know how far to go with the refining process because the conditions of use in an engine vary so much that the benefits of some certain kind of refining may be offset.

The vehicle user is interested chiefly in the quantity of oil his engine uses and whether carbon will be deposited in quantities that will be detrimental. The only way in which relative consumption can be determined is to operate the engine under definitely regulated conditions, declared the speaker, who said that the company with which he is connected has found no relative difference in consumption of Eastern and Western oils. All large oil companies make good lubricating-oils, because they have proper facilities and cannot afford to market poor oils, and some small reputable companies also make good oils. The choice of an oil therefore resolves itself into the question, from which one the most value will be derived. The first lubricating-oils on the market

Laurence T. Wagner

T. F. Ott

were Eastern oils and, because their relatively high price was established, they have always sold at an advance over Western oils. It is difficult to place a new product on the market and convince the public of its quality.

Oil does not "wear out," but it burns completely or partially in an internal-combustion engine. Mr. Ott declared he had deliberately run his own car 5000 miles without changing the oil in the crankcase, and no harm was done. The car is equipped with an air-cleaner, an oil-filter and an oil-reclaimer or rectifier. After running it less than 1500 miles he found 7.7 per cent of gasoline in the crankcase oil. The reason that oil companies recommend changing the oil after every 500 or 1000 miles is that the oil becomes diluted with fuel and contaminated with road dust and condensed water-vapor. The number of miles one gets with an oil is not the most important consideration, because the oil is or should be changed after frequent intervals. Carbon deposition and the character of the deposit are of more importance.

Should Test Viscosity at Two Temperatures

Speaking first in the discussion, G. F. Folsom, of the General Petroleum Corporation, stated that the viscosity test is a relic of the early days of the automobile industry when 100 deg. fahr. was probably the working temperature. With the higher operating-temperatures of today, oils should be classified by viscosity at two different temperatures, one that

would represent the average operating-temperature and the other represent the mean temperature when starting engines. Viscosity of Western oils increases rapidly as the temperature is reduced from 100 to 25 deg. and most of the difficulty with their use arises when starting. Films of oil from previous operation adhere to the cylinder-walls but the oil-pump will not force the cold oil when starting, hence the film is broken down. The viscosity does not change evenly with change of temperature; the next best thing is an oil with a rate of change as low as possible.

Some so-called paraffin-base oils have an apparent flow-test of about 30 deg., due to minute paraffin particles, but this solidity disappears, he said, with one turn of the crank-shaft; therefore the flow-test is not important and does not represent the true solidity of the oil at starting. A little-understood quality known as "oiliness" determines the spreading and lubricating value of an oil.

T. A. Fitch, testing engineer of the Los Angeles City laboratory, said that years ago the city, in an effort to obtain unbiased information, started to find out for itself the lubricating value of different oils in actual service. It used a device called a motor check by means of which various oils can be fed to a machine successively. It has been necessary to make-over the device considerably, but he said he believes the city engineers are finding out something as to how to evaluate motor oils. They cannot make public any of the information at present and probably never will want to.

Why Oils Are Refined to Light Color

C. W. Christian, of the Pennzoil Co., inquired why, if the chemically active molecules make Western oils superior, the large refineries go to so much trouble and expense to refine them out of the oil. Mr. Ott replied that it is believed the presence of the unsaturated hydrocarbons is to some extent responsible for one oil having more oiliness than another. The reason for extensive refining of oils is that the light-colored oils sell best. Unrefined lubricating distillate can be used with entire success but would not sell. Danger exists in over-refining oils. Red engine-oil designated 5 on the color scale is as good as a 3 oil. If all the unsaturated compounds were removed from the California oils, the color would be almost water-white. He said he believes, however, that a red oil would be oilier than this pale oil. Eastern oils are produced principally from the heavier grades of petroleum by combining a low-viscosity Eastern neutral with an Eastern bright oil. This makes a dark-red medium and heavy motor-oil.

Commenting on this phase, C. C. Moore, Jr., research engineer of the Union Oil Co., remarked that recently he made a test by dropping Nujol on a metal plate having a surface with as high a polish as could be obtained in Pasadena. The medicinal oil did not wet the surface, or spread, at all but formed in individual droplets. Plain cylinder-oil was then tested and it spread out. This test, he said, was confirmation of Mr. Ott's theory that refinement is detrimental to the wetting tendency of an oil.

As a carbureter man, J. F. Dixon said he was interested in the heat in the head of the piston, and asked what element in an oil forms carbon under the head of the piston. Mr. Ott answered that the carbon residue left when oil is burned forms cokene in the absence of enough oxygen to burn the residue away. If the temperature of the pistons is so great that residue is left on the under side, Western oils will leave less carbon than will Eastern oils.

H. A. Davis, of the Standard Oil Co., remarked that many persons have a false idea of the temperatures in the combustion-chamber. With a thermometer inserted through the pet-cock of the old-type engine, the highest temperature he had ever been able to get was 450 deg. fahr. with the spark retarded and the fuel mixture enriched as much as possible. This was the average operating-temperature in the combustion-chamber. The average temperature in an automobile traveling 30 m.p.h. does not much exceed 250 deg., he asserted. The cooling effects of the incoming charges and the water circulating in the jackets reduce the combustion-chamber temperature. Today we do not have to contend with extreme temperatures in the combustion-chambers or on the cylinder-walls.

Concluding the discussion, Mr. Wagner mentioned that the success an operator has in handling his individual lubricating-problems depends much more on how well he does this than on the brand of oil he buys. Discussion of the finer points of oils carries one into the region of applied petroleum chemistry, which is rather difficult to understand unless a man has had long training in this line. If the operator's lubricating problems are handled intelligently, lubricating-oils bought from any reputable company will give satisfactory results.

EVOLUTION OF LIGHTER-THAN-AIR CRAFT

Dr. Karl Arnstein

The Past, Present and Future of Lighter-than-Air Craft was the huge subject undertaken for its April 21 meeting by the Dayton Section. Dr. Karl Arnstein, vice-president in charge of engineering for the Goodyear-Zeppelin Corporation, was the principal speaker. He was educated at the Technical University of Prague and was awarded the degree of doctor of technical science in 1912. He was chief engineer of the Luftschiffbau Corporation at Friedrichshafen for some years previous to coming to this Country and has supervised the design and construction of more than 90 rigid airships, including the Los Angeles.

Dr. Arnstein gave a very interesting review of the development of lighter-than-air craft from its beginning, laying particular emphasis on the work by Count Zeppelin in developing the rigid type of airship to a practicable status in spite of almost insurmountable difficulties and repeated failures.

At the dinner held jointly with the members of the Engineers Club at their headquarters, about 50 members and guests were in attendance. Major Frank M. Kennedy, U. S. A., chief of the lighter-than-air craft branch of the Materiel Division of the Army Air Corps, gave an interesting description of his flight from Germany to the United States in the airship Los Angeles.

MAGNESIUM AND ITS POSSIBILITIES

The early development of magnesium, the difficulties that had to be overcome to bring this light metal to its present state of usefulness and the possibilities of its use in the future were told by S. K. Colby, president of the American Magnesium Co., at the monthly meeting of the Buffalo Section at the Hotel Statler the evening of April 5. A number of samples of fabricated pieces of magnesium were exhibited by the speaker. More than 60 members attended the meeting and showed great interest in the subject.

At the business meeting prior to the technical session the Section elected John C. Talcott, acting chief engineer of the Pierce-Arrow Motor Car Co., to represent the Buffalo Section on the Nominating Committee for election of officers of the Society for 1928 at the Semi-Annual Meeting. J. W. White, chief engineer of the Wire Wheel Corporation of America, was elected as alternate if he attends the meeting, and Earl W. Kimball, engineer in the manufacturers' service division of the Vacuum Oil Co., was selected a substitute alternate in event that Mr. White is not present at French Lick Springs.

Following presentation of a summary of the proposed changes in the Constitution of the Society, it was voted to refer the matter to the governing board of the Section with the understanding that the board will make its suggestions at the Summer Meeting.

Tendencies in Research at Engineering Colleges

By A. A. Potter[1] and G. A. Young[2]

Annual Meeting Paper

ABSTRACT

ALTHOUGH the population of the United States is less than one-twentieth of that of the world, American inventive genius is responsible for more than two-thirds of the epoch-making inventions; but it has added very little to fundamental scientific knowledge. In the earlier days of industrial development, much dependence could be placed upon the individual inventor, but waiting for chance discoveries by men of genius is no longer practicable. Research laboratories are now used to acquire new and exact knowledge of facts, to develop new products, and to lower manufacturing costs.

Research improves old industries, builds up new ones, and can be carried on either by industry or by educational institutions. Research work at universities has several advantages over that carried on in industrial laboratories: University research workers are free from interruption, are in an atmosphere sympathetic to research, and their work reacts beneficially on the students who are being trained in the universities. Industry needs engineers who will extend the frontiers of knowledge and develop new processes for the conservation of the National resources and for the elimination of waste. These men can be developed if industry will bring its research problems to the universities, as is the case in Germany.

About 40 American engineering colleges are conducting organized engineering research. In about 9 institutions, the funds for this purpose come purely or entirely from State appropriations, which, during the year 1924-1925, amounted to about $123,000. During the same year about 20 institutions set aside approximately $451,000 for engineering research. During 1924-1925, 15 engineering colleges received more than $500,000 for research through cooperative relations with industry. Thus, the total annual expenditure for research by engineering colleges is more than $1,000,000, or, roughly, one-thirteenth of the amount spent by these colleges for undergraduate instruction, not including interest on the educational plants or depreciation.

Tables give definite data concerning a great variety of investigations now being carried on by the engineering colleges of the United States in cooperation with industries, public utilities, State governments, the Federal Government and engineering societies.

Cooperative relations between Purdue University and the American Railway Association have resulted in extensive studies for which the latter has appropriated more than $500,000 during the last 2 years. During the same period, the automotive industry has contributed less than $10,000 to all the engineering colleges of the Country for cooperative engineering research.

The automobile industry has a clear-cut obligation to provide engineering colleges with special equipment and funds for the solution of new problems through research, in order that the automotive engineers of the future shall have the intellectual curiosity and the ability to extend the frontiers of automobile engineering knowledge. More liberal support for engineering research at colleges and universities will improve the quality of the engineering-college graduate, will advance basic knowledge in automotive engineering, and will increase the supply of trained personnel available for positions in the research laboratories of the automobile industry.

ALTHOUGH the United States has less than one-twentieth of the population of the world, our inventors are responsible for more than two-thirds of the epoch-making inventions that we now enjoy. The telephone, the telegraph, the electric light, the motion picture, the talking-machine, in fact, most of the wonders of our age, are the results of American inventive genius. Our people have, however, added very little to fundamental scientific knowledge.

Our Country represents about one-fifteenth of the land area of the world, but our natural resources enable us to produce a very large share of the world's supply of oil, coal, iron, steel, copper and aluminum. These wonderful natural resources combined with the genius of our people have enabled us to produce in this Country a material welfare that is the greatest in the world; but, on the other hand, we have had to depend largely upon other countries for new scientific knowledge.

Need of Research Knowledge

In the earlier days of the development of industry, much dependence could be placed upon the individual inventor, but, with the increased size and complexity of modern industry, it is not practicable to wait upon chance discoveries by men of genius. Leaders of industry are convinced that research laboratories must be used to acquire new and exact knowledge of facts, to develop new products, and to lower manufacturing costs. Research is of value in improving old industries and in building up new ones.

So much has been accomplished through invention that many persons are of the opinion that everything worthwhile has been discovered and that the engineer is concerned only with the application of already existing knowledge. This idea is erroneous, for industry is confronted today with many problems of the most serious nature that can be solved only if the best brains of the Country are constantly at work on research.

Research can be carried on either by industry or by educational institutions, such as Purdue University. Research work carried on by universities has several advantages, as compared with that carried on in industrial laboratories: university research workers are free from interruption; they are in an atmosphere sympathetic to research; and their work reacts most beneficially in improving the main output of those institutions, the students who are being trained in them. Industry needs engineers who will extend the frontiers of knowledge and will develop new processes for the conservation of our resources and for the elimination of waste. This can be accomplished, if industry will bring its research problems to the universities, as is the case in Germany, where research work is being carried on to a large extent in the technical universities.

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RESEARCH IN ENGINEERING COLLEGES

It is most gratifying that about 40 American engineering colleges are carrying on organized engineering research. In about 9 institutions, the funds for this purpose come entirely from State appropriations, and these State grants for research, during the year 1924-1925, amounted to about $123,000. During the same year about 20 institutions set aside approximately $451,000 in their engineering college budgets for engineering research. Fifteen engineering colleges during 1924-1925 received more than $500,000 for research through cooperative relations with industry. Thus, the total annual expenditure by engineering colleges for research is about $1,000,000, or roughly one-thirteenth of the amount spent by these colleges for undergraduate instruction, not including the interest on educational plants and depreciation.

The land-grant colleges, such as Purdue University, have been very active for many years in research that is of value to the industry. Tables 1, 2 and 3 were presented at the 40th Annual Convention of the Association of Land-Grant Colleges, in the City of Washington, in November, 1926. From these tables, it is evident that 28 of the 48 land-grant colleges have organized engineering experiment-stations and are spending annually about $650,000 for research. The total amount spent by 32 land-grant colleges for engineering research in 1925-1926 is given in Table 3 as $851,921.

RESUME OF RESEARCH IN AMERICAN ENGINEERING COLLEGES AND UNIVERSITIES IN 1925-1926

The following resume should prove of interest in showing what phases of research are being undertaken by State and American land-grant engineering colleges and universities:

(1) The Cornell University Engineering Experiment-Station has cooperated with industries for a number of years in research projects of considerable magnitude. No data are available as to details

(2) The Engineering Experiment Station of the University of Illinois has been cooperating with industry in the following projects:

(*a*) The Austin Mfg. Co. has contributed $1,200 each year for a period of 2 years from Feb. 1, 1925, to pay the stipend of two research graduate assistants in highway engineering. One assistant is making a study of the maintenance of gravel roads

(*b*) Investigation of the fatigue phenomena of metals is carried on in cooperation with the engineering division of the National Research Council, the Engineering Foundation, the General Electric Co., the Allis-Chalmers Mfg. Co., the Copper & Brass Research Association, and the Western Electric Co. The amount appropriated each year approximates $15,000

(*c*) An investigation of the fatigue of steel castings has been carried on in cooperation with the American Steel Foundries since the spring of 1925. The amount contributed by the American Steel Foundries is $2,000

(*d*) In cooperation with the National Warm-Air Heating and Ventilating Association, an investigation of warm-air furnaces and heating-systems has been carried on since October, 1918. The activities of this investigation were expanded last year by the addition of the warm-air-heating residence valued at $22,800. The annual expenses of the investigation average $8,000

(*e*) The Illinois Gas Association furnishes

TABLE 1—STATISTICS OF ENGINEERING EXPERIMENT-STATIONS OF LAND-GRANT COLLEGES AND UNIVERSITIES[3]

State	Year Station Was Started	Funds, 1926-1927: From Legislature	From College	From Other Sources	Staff: Full-Time	Part-Time: With Pay	Without Pay	Bulletins since Jan. 1, 1926
Arkansas	1920		$2,000		1		5	
Colorado	1917	$11,000			2	3	2	
Illinois	1903		92,730	$72,000	36	20	50	9[a]
Indiana[4]	1917		25,640	127,000	68[b]	10	8	1
Iowa	1904	45,000	12,000		8	8	5	4
Kansas	1910		20,000	30,000	11	38	10	3
Maine	1913		3,325	2,200	1	3	2	4
Maryland	1921		3,500	3,500		5	4	
Michigan	1924		15,000		2	4	6	4
Minnesota	1921		7,030	1,275		5	13	1
Mines		30,000	31,860		10	14	4	2
Missouri	1909	5,000				1	3	1
Montana	1924							
Nebraska	1923		300	7,000	2		3	
Nevada	1921		500					1
New Jersey	1926	5,000				2		
New York	1923		5,000	2,000	2	2		2
North Carolina	1923		8,700		2		7	
Ohio	1913	10,000			5	15	5	2
Pennsylvania	1908		16,030	500	5	3	7	3
South Carolina	1924		2,000			1	3	
Tennessee	1921		1,550	331		1	5	
Texas	1914	2,000	2,000	4,000	1	3		3
Utah	1918							
Vermont	1922		1,500					
Virginia	1921		950			1	6	
Washington	1919		7,500		1	3	6	1
West Virginia	1921		6,000			5	7	
Wisconsin	1914		20,000	6,000	4	7	12	
Total—28		$108,000	$285,115	$255,806	161	154	173	

[3] Reported by the committee on engineering experiment-stations of the Association of Land-Grant Colleges, at a meeting of the engineering section held in the City of Washington on Nov. 17, 1926.

[4] In Indiana, the figures refer to Purdue University, which is the only State engineering college in Indiana carrying on research.

[a] Including two circulars.

[b] Includes 60 men on American Railway Association air-brake project.

TABLE 2—STATISTICS OF ENGINEERING RESEARCH OF LAND-GRANT COLLEGES AND UNIVERSITIES NOT HAVING ENGINEERING EXPERIMENT-STATIONS AS OF NOV. 1, 1926

	Funds, 1926-1927			Staff			Bulletins,
	From Legis-	From	From Other	Full Time	Part Time		since Jan. 1,
State	lature	College	Sources		With Pay	Without Pay	1926
Arizona	$25,000			3	4		4
Florida			$500			2	
Idaho		$2,000	500		2		
Massachusetts		75,000	100,000	30			
Total	$25,000	$77,000	$101,000	33	6	2	4

$1,200 each year for the maintenance of two research graduate assistants in gas engineering. These assistants have been maintained since 1916

(*f*) An investigation of plumbing is carried on in cooperation with the Illinois Master Plumbers' Association with an appropriation of $1,800 annually. This has been in progress since April, 1925

(*g*) The department of railway engineering cooperates with the Illinois Central Railroad in an investigation of railroad signaling

(*h*) The University of Illinois Engineering Experiment-Station is also cooperating with a committee that represents six State public utilities in studies of direct value to the utilities of the Nation. The appropriation by the cooperating agency has been $25,000 per year for 4 years

and the American Society of Civil Engineers. About $6,000 annually for a number of years has been spent on this investigation

(*b*) The strength of clay sewer-pipe encased in different thicknesses of concrete, in cooperation with the Clay Products Association, which is paying about $550 for tests of 24-in. pipe

(*c*) The strength and loading of highway culverts, the tractive resistance and the fuel consumption of motor-vehicles on various types of highway surface, and highway bridge impact, in cooperation with the Bureau of Public Roads, which since April, 1922, has made the following expenditures: 1921-1922, $1,571; 1922-1923, $8,216; 1923-1924, $10,797; 1924-1925, $21,462; 1925-1926, $7,000

(*d*) Several interesting investigations in cooperation with the ceramic industry of Iowa

TABLE 3—SUMMARY OF TABLES 1 AND 2

Funds, 1926-1927		Personnel	
Legislature	$133,000	Full-Time	149
Institutional	362,115	Part-Time	158
Other	356,806	Unorganized	175
Total	$851,921	Total	482

Total Bulletins for the First 10 Months of 1926......45

(*i*) It has also cooperated with the American Gas Association in a study of the steaming of horizontal gas-retorts; with the Illinois Central Railroad in research pertaining to railway-signal equipment; and with several railroad companies in investigations of rail-joints and special railroad equipment. In cooperation with the American Railway Engineering Association, it is carrying on studies of large steel-rollers

(*j*) The University of Illinois Engineering Experiment-Station, in May, 1925, reported to the New York State and New Jersey Interstate Bridge & Tunnel Commissions on ventilation tests for use in the construction of the Hudson River Vehicular Tunnel. The amount appropriated for this work was between $40,000 and $50,000. The investigation required about 4 years for its completion

(*k*) The University of Illinois Engineering Experiment-Station is conducting a cooperative investigation with the Bureau of Public Roads to secure data on the factors affecting the design of drainage ditches and the improvement of natural channels to minimize the damage from floods. This investigation was begun in 1925. The United States Government furnishes one man on full time

(3) The Engineering Experiment-Station of the Iowa State College has carried on investigations dealing with:

(*a*) Culvert pipe, in cooperation with a joint committee of the American Concrete Institute, the American Association of State Highway Officials, the American Railway Engineering Association, the American Society for Testing Materials, the American Concrete Pipe Association,

(*e*) The utilization of farm wastes. The use of corn cobs and corn shucks for paper manufacture is being studied in connection with a new process developed by the Station

(*f*) Other development work that has been carried on has resulted in a manless plow and several other machines of value to the farmer

(4) The Engineering Experiment-Station of the Kansas State Agricultural College has cooperated with industry in:

(*a*) Tests of automatic ventilators. The value of ventilators donated is about $400

(*b*) Tests of oil-burners for house heating, in cooperation with the manufacturers of burners. The value of the equipment donated for tests is about $200

(*c*) Studies of the air-resistance of motor-vehicles for about 4 years. The contribution by the Bureau of Public Roads to date is about $15,000

(5) The University of Kansas Engineering Experiment Station has also cooperated with industry in research for a number of years. This research includes studies of Kansas coal, in cooperation with the coal producers, and of several special projects that are supported by the Chambers of Commerce of the cities of Kansas

(6) The Department of Engineering Research of the University of Michigan reports an expenditure of more than $50,000 per year for cooperative engineering research. The major projects include:

(*a*) Natural illumination. The study is in the third year

(*b*) Single-phase and fractional horsepower motors. Two years' work has been devoted to this subject

(*c*) Natural ventilation. This project is in its third year

(*d*) The cutting of metals. This study, in cooperation with Michigan manufacturers, has been carried on for 3 years

(*e*) Admiralty and Muntz metals. This investigation has continued for 2 years and involves the properties of these metals at high temperatures

(*f*) Development of a machine for automatically testing bearings for noise. This has continued for more than 2 years, with results of great value to industry

(*g*) Boiler feed-water treatment

(*h*) Studies of charcoal iron

(*i*) Refrigerating media

(7) The University of Minnesota Engineering Experiment-Station reports the following cooperative projects with industries:

(*a*) Transmission of heat through building materials, in cooperation with the Flaxlinum Insulating Co. The contribution by the cooperative agency has been $1,750 per year for 2 years

(*b*) Investigation of rotary pumps for viscous oils, in cooperation with the Northern Fire Apparatus Co. The appropriation by the cooperating agency has been $750 per year

(*c*) Behavior of asphalt under temperature variation, in cooperation with McLaughlin & Sons. Contribution, $500

(8) The University of Missouri Engineering Experiment-Station is cooperating with industry in the following way:

(*a*) The National Lime Association has furnished $3,000 during a period of 18 months for a study of the effect of lime products on dirt roads

(*b*) The Southeastern Missouri Sunflower Growers' Association has furnished material for studies of the commercial uses of sunflower oils

(*c*) The Radium Co. of Colorado, the United States Radium Corporation and the Keystone Metals Reduction Co. have cooperated in an investigation of processes for the extraction of radium from carnotite ores

(9) The Ohio State University Engineering Experiment-Station, besides the cooperative investigations with the ceramic industry, which it has practically created, is at present studying the betterment and the gasification properties of Ohio coals, in cooperation with the Southern Ohio Coal Association, the Ohio Oil Gas Men's Association, the American Gas Association, and the Southern Ohio Pig Iron & Coal Association. The contribution by the cooperating agencies has been $10,000 for 2 years

(10) The University of Cincinnati, Cincinnati, Ohio, has been carrying on the following studies:

(*a*) It has cooperated for about 4 years with the Tanners' Council of America in research of a fundamental character and of direct value to leather manufacturers

(*b*) Research of a basic character in lithography was begun March 1, 1925, in cooperation with the Lithographic Foundation

(*c*) In cooperation with the Civic Commercial Club and the Union Gas & Electric Co., of Cincinnati, it is making a study of the sub-surface resources of Cincinnati

(11) North Carolina Engineering Experiment-Station reports tests of the strength of poles for the Carolina Light & Power Co. The public utility company is furnishing poles valued at about $3,500

(12) The Pennsylvania State College Engineering Experiment-Station is studying the following problems:

(*a*) In cooperation with eight Pennsylvania manufacturers, it is attacking problems of cold storage. The appropriation is $800

(*b*) In cooperation with the Pennsylvania Railroad, an investigation is being made of refrigerator-cars

(*c*) In cooperation with the United States Navy and with several private parties, a study is being made of internal-combustion engines. The contribution in materials and apparatus to date is valued at about $11,000

(*d*) In cooperation with the American Society of Heating & Ventilating Engineers, an investigation is being carried on dealing with heat transmission. Contribution, $500

(*e*) In cooperation with the Bureau of Mines, investigations are being made of the explosiveness of flour-mill and elevator dusts

(13) The Engineering Experiment-Station of Purdue University is studying:

(*a*) The causes and prevention of the discoloration of Indiana limestone, in cooperation with the Indiana Limestone Quarrymen's Association. The appropriation by the cooperative agency is $4,000 per year, plus materials valued at about $500 per year. After the project has continued for 2 years, the appropriation was renewed for the third year, effective April 1, 1926

(*b*) Automobile carbureters, manifolds, spark-plugs, pistons, piston-rings, and cylinders, also special problems of steering, detonation, supercharging, fuels, and the like, in cooperation with the automotive industry. The contribution by cooperating agencies has been mainly equipment and fuel oils

(*c*) The standardization of tractors, in cooperation with tractor manufacturers and the War Department. The contribution by cooperating agencies has been mainly in equipment, fuel, oil, and $1,200 for special assistance

(*d*) Insulators for high voltages, up to 600,000, in cooperation with the manufacturers of insulators

(*e*) Brake-shoes, pulleys, insulators, materials of construction, and a variety of devices for industry. The income from such commercial tests has varied from $3,000 to $6,000 per year for several years

(*f*) Celite as an insulating material, in cooperation with the Celite Products Co., through a fellowship valued at $1,000 per year for 1 year

(*g*) The steaming-quality of Indiana coals and methods for improving their quality, in cooperation with the mining interests of Indiana

(*h*) Special subjects in cooperation with the Indiana Sand & Gravel Association

(*i*) Power-brakes and power-brake appliances, in cooperation with the American Railway Association. This study was undertaken on March 1, 1925. The amount expended by the cooperating agency from March 1, 1925, to Jan. 1, 1927, has been more than $350,000. This investigation will involve an additional expenditure of about $500,000 before it is complete

(*j*) Brake-shoes, rail-joints, and special rail-road-equipment, in cooperation with the railroads

(*k*) The American Railway Association has also contracted to begin a cooperative study of draft-gears. The equipment to be used in these studies will consist of a drop-testing machine using a 27,000-lb. weight. Expenditure by the cooperating agency up to Jan. 15, 1927, includes more than $50,000 for a special building and equipment; and in addition an operating salary-budget of $15,000 for the year 1927

(*l*) Buried lead-cables, in cooperation with the telephone utilities; high-voltage insulators, elec-

tric meters, and the emergency braking of electric cars, in cooperation with electric-light and power utilities.

(*m*) The effect of moisture on the strength of concrete and on the warping of concrete road-slabs; the effect of small amounts of reinforcement in preserving the surface of concrete against cracks; the fatigue of concrete; and a new test for the surface hardness of concrete, measured by the impression of a standard steel-ball, in cooperation with the Bureau of Public Roads. These studies have continued for about 4 years, the Bureau of Public Roads furnishing two men on full time

(14) The University of Tennessee Engineering Experiment-Station is cooperating with:

(*a*) The American Limestone Co. in an examination of a special grade of limestone as a basis for concrete. A contribution of $600 has been made by the cooperating agency

(*b*) The Southern Appalachian Coal Operators Association, in a study of the properties of Kentucky and Tennessee coals, toward which the Association has contributed $1,500

(15) The State College of Washington is cooperating with the State Automobile Association in the study of the relation of road surface to the wear of automobile tires

(16) The University of Washington has been cooperating with local industries in studies of centrifugal-blowers, the heat-treatment of cement, the intakes for high-velocity flumes, the flow of water in concrete and vitrified-clay sewer-pipe, and coal-washing problems. One hundred and sixty thousand dollars has been donated to the University of Washington by outside sources during the last 3 years for investigations on the K-B propeller.

(17) The West Virginia University Engineering Experiment-Station is cooperating with the Gasoline Recovery Corporation in a study of absorption materials for the recovery of gasoline.

(18) The University of Wisconsin Engineering Experiment-Station has the following projects, in cooperation with industry:

(*a*) A study of pipe-bend losses, in cooperation with the Vilter Mfg. Co. and the Crane Co., who have furnished pipe-bends for this study

(*b*) Service rendered by the electrical standards laboratory to the State, somewhat analogous to the service rendered to the Nation by the Bureau of Standards. An established schedule of fees is used for such service.

(*c*) Studies of the friction of line-shafting, welded joints, steel chains, the fatigue of rock-drills, and riveted and bolted joints, in cooperation with Wisconsin industries. The appropriation by cooperating agencies is $2,400, plus special equipment and specimens

(*d*) Two fellowships along electrical engineering lines supported by the Wisconsin Utilities Association, at a cost of $1,000 per year. The Gas Utilities have supported one fellowship since 1917 by providing $500 per year for this purpose. The Wisconsin River Light & Power Co. has contributed $500 for research

(19) The Massachusetts Institute of Technology Plan. Besides research work in the engineering colleges and universities that have engineering experiment-stations, the manner in which research work is accomplished at the Massachusetts Institute of Technology is worthy of special mention. This interesting plan, which was put into practice in 1919, is a cooperative arrangement by which industrial concerns in search of aid in scientific and engineering research pay the Institute stated sums of money as retainer fees for a period of 5 years, in return for which they have at their disposal, with certain limitations, the research staff and facilities of the Institute. The agreed-to services of the Massachusetts Institute of Technology in connection with the plan include:

(*a*) The use of the personnel records of alumni for the purpose of assisting contractors in locating desirable men

(*b*) The libraries of the Institute which are open to the representatives of contractors

(*c*) Arrangements by which representatives of contractors can consult with members of the Institute staff

(*d*) Advice given by the Institute to contractors when special problems are to be solved or tests carried out. In cases that call for work in the Institute laboratories by members of the staff, the contractor is expected to pay such sums as are mutually agreed upon by him and the staff. The overhead expense varies with the nature of the service but averages about 50 per cent

The Division of Industrial Cooperation and Research, which administers the Massachusetts Institute of Technology plan, acts as a clearing-house in which the questions of the contractors may be discussed, planned for and attacked in a prompt and efficient manner. Prof. Charles L. Norton, director of the Division, states that it is very difficult to make even a rough estimate of the amount of money that has been spent on industrial research at the Institute. He believes, however, that this has been in excess of $175,000 annually.

Resume of Cooperative Research by State and National Engineering Societies, Associations and Private Manufacturing Companies

It might be interesting to give a brief resume of the cooperative research work carried on in 1925-1926 by colleges and universities for State and National engineering societies, associations and private manufacturing companies.

State and Federal Governments.—The State and Federal Government Bureaus appropriated $51,000 last year in carrying on 23 projects in 19 universities and colleges. Prior to 1927, they have appropriated $193,500. The following is a list of the bureaus:

Bureau of Public Roads
State Highway Departments
Navy Department
War Department
Bureau of Mines
State Bureaus of Mines
Geological Survey
State Geological Surveys
State Conservation Departments

State and National Associations.—The State and National Associations listed below are supporting research to the extent of $50,150 per year, with total appropriations to date of $233,500 to 19 engineering educational institutions for the investigation of 22 projects:

National Research Council
Engineering Foundation
American Association of State Highway Officials
National Warm-Air Heating & Ventilating Association
Illinois Gas, Ohio Gas and American Gas Associations
New York State and New Jersey Interstate Bridge & Tunnel Commissions
Clay Products Association
South Ohio Coal and Indiana Coal Associations
South Appalachian Coal Operators Association
Tanners Council of America
Indiana Sand & Gravel Association

Public Utilities.—The public utilities, gas and electric, 12 in number, of several States gave $30,000 in 1925-1926 to assist 12 colleges and universities in car-

rying on research work. Up to the present time they have appropriated $90,000 in 5 years for this work.

National Engineering Societies.—Five national Engineering Societies are cooperating with seven colleges and universities in the same number of projects at an annual cost of $20,500 and with an expenditure of $59,500 to the end of 1926. These societies are the American Concrete Institute, the American Society for Testing Materials, the American Society of Civil Engineers, the American Society of Heating & Ventilating Engineers, and the American Society of Mechanical Engineers.

It is significant to note that uptodate there is no record of this Society's having appropriated any funds to carry on engineering research in the universities and colleges.

American Railway Association.—The railroads of this Country have been noted for their conservatism, yet, through the American Railway Association, which includes all the railroads of the United States and Canada, they have spent $135,000 in four universities and $215,000 up to 1926. This covers research work on brake-shoes, air-brakes, draft-gears, rails, rail-joints, signal-apparatus and miscellaneous equipment for increasing the efficiency of locomotives.

In addition to the above, the American Railway Association has spent about $400,000 at Purdue University during the last 2 years for an investigation of air-brakes, with an added appropriation of $255,000 for carrying on this work in 1927. The American Railway Association, in addition to appropriating this sum for air-brake tests, has just completed a building at Purdue University and has purchased special equipment for an investigation of draft-gears at an expenditure of about $60,000. It has also set aside an operating budget of $15,000 for 1927 for conducting the draft-gear tests. This will mean a total expenditure of about $700,000 by the American Railway Association at Purdue University in 3 years. Besides the cooperation of the railroads through their association, the Illinois Central Railroad and the Pennsylvania Railroad are carrying on special investigations in cooperation with two universities.

The National Electric Light Association.—The National Electric Light Association is cooperating with 17 colleges and universities in studies of rural electrification. This cooperative project involves an expenditure of about $250,000 per year, one-half of which is being contributed by the utilities.

Private Manufacturing Companies.—During the last year, 67 manufacturing companies have given $273,650 to universities and colleges for research on 34 cooperative projects. The annual appropriation for the university year of 1925-1926 was $100,300. Although none of these 67 companies is an automobile manufacturing company, several of the companies listed manufacture automobile parts and accessories.

Automobile Manufacturing Companies.—During the last 2 years, four automobile manufacturing companies have expended $6,900 in four research projects in four universities.

Civic Clubs.—The Chambers of Commerce and other civic service clubs in several cities have cooperated with their State educational institutions in many problems pertaining to city welfare.

Research Funds From Other Sources.—In addition to the above, universities and colleges receive large sums annually for research from two other sources, namely,

(1) The Guggenheim Fund of $2,500,000 for aeronautics was announced about a year ago. The trustees of the fund have already made a considerable portion of this fund available for research at engineering colleges

(2) The American Gas Association has also set aside the sum of $250,000 for research

Summary of Appropriations to Engineering Colleges and Universities for Research From Outside Sources in 1925-1926.—A brief summary of the appropriations from outside sources is given in Table 4. This shows that 149 colleges and universities receive an annual appropriation of $520,850 from 123 organizations for research on 123 projects and that the total amount expended on these investigations is about $1,367,000.

TABLE 4—SUMMARY OF APPROPRIATIONS TO ENGINEERING COLLEGES AND UNIVERSITIES FOR RESEARCH FROM OUTSIDE SOURCES IN 1925-1926

	Number of Colleges and Universities Involved	Number of Projects	Appropriations Annual	Total
State and Federal Bureaus	19	23	$51,000	$193,500
State and National Associations	19	22	52,150[c]	233,500[c]
Public Utilities	12	12	30,000	60,000
Engineering Societies	7	7	20,500	59,500
American Railway Association	4	4	135,000[d]	215,000[d]
National Electric Light Association	17	17	125,000	325,000
Manufacturing Companies	67	34	100,300	273,650
Automobile Manufacturing Companies	4	4	5,900	6,900
	149	123	$519,850[e]	$1,367,250[e]

[c] This does not include the American Gas Association which is giving $100,000 per year.

[d] The amount expended in connection with air-brake research at Purdue University has totaled about $400,000 to date. The budget for 1927 includes $255,000 for air-brakes and $15,000 for draft-gear investigation.

[e] Does not include the sum of $175,000 given annually to the Massachusetts Institute of Technology.

General Observations As to the Services Rendered

A careful study of the facts set forth thus far enables some general observations to be made as to the services rendered by the engineering colleges and universities.

Services Rendered to Manufacturers.—Practically every engineering college is serving one or more individual manufacturers by special tests and investigations of their products. In some cases the results of these commercial tests are published for the benefit of the public, but in the majority of cases they are the exclusive property of the manufacturer who pays for the investigation.

Services to the Automobile Industries.—Universities and colleges have carried on investigations that are directly or indirectly of interest to the automobile industries on a non-cooperative basis, excepting some cases in which the industries have furnished or loaned the equipment or apparatus that they wish to be tested. The list of these investigations is long; in many instances the results have appeared in the form of bulletins or papers. Only a few of the kinds of equipment tested can be mentioned. These include such parts as engines, carbureters, manifolds, spark-plugs, pistons, piston-rings, radiators, starting and ignition systems, dust-collectors, oil-purifiers, superchargers, tires, lubricating-oil and fuels. The effects of detonation, high compression, air-resistance, riding-qualities, acceleration, brakes, and many other features have been covered. A glance at this list immediately suggests the fact that very few of the parts mentioned were furnished by the automobile companies, but were furnished chiefly by the universities or by supply companies that manufactured the accessories and sold them to the automobile companies for assembling.

Service to Manufacturing Companies.—During the last year, 67 manufacturing companies have secured the services of 30 universities and colleges for research on 34 projects. None of these 67 manufacturing concerns is an automobile manufacturing company.

Service to State and Federal Governments.—Cooperation between the State engineering colleges and universities and the Federal and State Bureaus of Public Roads, the Mines, Highway, and Conservation Departments, and the Geological Surveys is general. In several instances, engineering institutions have rendered a special and useful service to the War and Navy Departments.

Service to State and National Associations.—The engineering educational institutions, to the number of 19, have cooperated in 22 projects with 12 State and National associations.

Services to Public Utilities.—It is of interest to know that 12 public-utility companies have recognized the possibilities of cooperative research with the same number of engineering universities.

Service to the National Engineering Societies.—During the last year, five of the great National engineering societies have utilized the research services of the engineering colleges. So far, this Society has not cooperated to such an extent as to have their cooperation reported.

Service to Miscellaneous Agencies.—Besides the services rendered to the above-named agencies by the engineering colleges and universities, the cooperation of the American Railway Association, the National Electric Light Association, the American Gas Association and the Trustees of the Guggenheim Fund with educational institutions is of significance because of the amount of money annually involved.

General Summary

To present the whole subject of Tendencies in Research at Engineering Colleges in a comprehensive manner, a brief summary of the significant facts contained in the mass of information given in the preceding pages will conclude this paper.

Institutional Research.—Forty American engineering colleges are carrying on organized engineering research, of which 9 received $133,000 from State appropriations and 20 set aside a total of about $362,000 in their college budgets for engineering research. These engineering colleges are employing 149 full-time and 158 part-time assistants.

Non-Cooperative Research.—In addition to the institutional research just cited, during the last year the universities and colleges have conducted 40 research projects at an annual expenditure of $350,000 without assistance from outside sources.

Cooperative Research.—One-hundred-and-forty-nine engineering colleges and universities last year received from State and National engineering societies, associations and private manufacturing companies, totaling 123 organizations, an annual appropriation of more than $520,000 for cooperative research on 123 projects.

The Massachusetts Institute of Technology Research Plan.—The far-reaching plan of this institution, by which 97 industrial concerns and public utilities are annually appropriating $175,000 for research of special interest to them, is giving excellent satisfaction to all the parties concerned.

Guggenheim Research Fund.—The trustees of the $2,500,000 fund for aeronautics have already set aside $550,000 for aeronautical research in five engineering universities.

American Gas Association.—This Association appropriates annually a large sum for research in the field that is of particular interest to it.

The Obligation of the Automotive Industry

The automotive industry has a clear-cut obligation to provide engineering colleges with special equipment and funds for the solution of new problems through research, in order to be certain that the automotive engineers of the future shall have the intellectual curiosity and the ability to extend the frontiers of automobile engineering knowledge. More liberal support for engineering research at colleges and universities will improve the quality of the engineering college graduate, will advance basic knowledge in automotive engineering, and will increase the supply of trained personnel for the research laboratories of the automotive industry.

From the above it is seen that about $1,840,000 was expended in 1925-1926 in the engineering colleges and universities of America for research alone. From information already available, this amount will be exceeded in 1926-1927.

This summary has indicated that engineering colleges, such as Purdue University, are competent to undertake research projects that vary greatly in scope. Although the results of such cooperative investigations are directly of value to the industry, the by-products of such research relations between the engineering colleges and the industry result in a supply of scientifically trained research men. Engineering colleges that have good facilities for research attract men of superior mentality who desire to pursue graduate study as a preparation for a research career. Industries and utilities can also benefit themselves and stimulate graduate instruction in engineering by sending back certain of their selected employes to the engineering colleges for advanced study and research.

APPENDIX

Bulletins of the Mechanical Engineering Division of the Engineering Experiment-Station, Purdue University, of Interest to the Automotive Industry

Purdue University in the last 8 years has expended more than $150,000 for research that is of direct interest to the automotive industry, for which the automobile companies have contributed nothing. The published bulletins include:

No. 5—The Carburetion of Gasoline, by O. C. Berry and C. S. Kegerreis, in 1920

The object of this bulletin was to indicate the richness of the fuel to the air-mixture required by an engine under different running-conditions, in order that it may develop either maximum power or maximum efficiency.

No. 11—The Effect of Speed on Mixture Requirements, by C. S. Kegerreis and G. A. Young, in 1923.

In this publication, data are presented to establish definitely the mixture-ratios required by an automobile engine, as they are affected more especially by speed. The results of this investigation supplement Bulletin No. 5 and fully outline the fuel-air ratios required by an internal-combustion engine of the throttling type at any speed and load-condition.

No. 15—Temperature Requirements of Hot-Spot Manifold, by C. S. Kegerreis and O. C. Berry, in 1923

This is a supplement to Bulletin No. 5 with added results from later investigations. It contains fundamental information, regarding the necessary and available temperatures to be obtained from the exhaust, that can be used by the industry in developing more efficient and useful devices for securing good performance from automotive machinery.

No. 17—Car Carburetion Requirements, by C. S. Kegerreis and O. Chenoweth, in 1924

The principal object of this publication is to analyze car performance and show, on a flow-rate basis, the desired metering-characteristics of a carbureter for level-road operation.

No. 21—Commercial Carbureter Characteristics, by C. S. Kegerreis, O. Chenoweth and M. J. Zucrow, in 1925

Engineering research may properly include a survey of available commercial products to the end that the possibility of improvement may be determined and intelligent economic design stimulated.

The mixture requirements of the gasoline used in automotive work having previously been determined and published, the present investigation was undertaken to determine by actual test how nearly the available commercial carbureters meet the service demands.

The final basis for analysis and comparison of commercial carbureters is the inherent waste of fuel, as compared in each case with the ideal engine-requirement, which was considered to be the setting giving the best performance as to proper idling, acceleration and power response.

No. 25—Flow of Heat in Pistons, by H. A. Huebotter and G. A. Young, in 1925

Whether we consider power, economy, smooth running, or friction in an internal-combustion engine, the piston stands out as an important factor. In the interest of good performance, the most desirable qualities in a piston are light weight, low temperature, and minimum distortion, but, since they involve conflicting principles, the accepted design is essentially a compromise.

Although no one piston is inherently best for all purposes, thermal considerations show that certain cross-section forms are fundamentally superior to others.

Detailed suggestions regarding ribs, piston-rings, ring-land radial clearance, and methods of expansion control are included in the bulletin.

These principles of piston design are developed by mathematical analysis of heat-flow from the hot gas, through the piston, and into the cylinder-wall. The theory of thermal flow is applied to the several components of the piston, and equations are derived for the solution of problems of general design. The analytical study was supplemented by laboratory tests on a large variety of standard and special pistons in the piston-testing plant.

BULLETINS IN COURSE OF PREPARATION

(1) Tractors
(2) Piston-rings
(3) Superchargers for automobile engines
(4) Kerosene as a fuel for automobiles
(5) The metering characteristics of venturi-tubes for carbureters

THE DISCUSSION

PROF. G. B. UPTON[5]:—Research, fundamental research in pure science as well as research in its practical applications, has been drifting away from the universities of the United States for the last 20 years, largely for reasons of finance. The financial difficulties of the universities have been tied up with their rapid growth, or overgrowth, for their numbers of students have increased faster even than the population of the Country. The university faculties have correspondingly been forced to give more and more of their time to "teaching school" and less to investigation or study. Simultaneously, the larger industries have discovered that research in pure science, as well as in advanced applications in their own line of production, is good business, for knowledge in pure science does not remain long idle in the sense of being without practical and profitable application. The most important research laboratories in pure science in this Country are now maintained by the industries, as, for example, the General Electric Co., at Schenectady, N. Y. This is not to say that the universities have stopped research work, but that their output of research results is far below our National need, and, indeed, far below the output of the industrial laboratories.

Under these circumstances the research function of the universities properly changes its emphasis and modifies its purpose. Its main purpose becomes the finding and developing of young men adaptable to the conduct of research work, men who, after a start at the university, will go to the industrial research laboratories to fill out their staffs in research in pure and applied science.

When research at the universities is done more to develop young men than to get new data of science, it is possible that the type of research problem at the universities may profitably be changed. It need not be true that the field investigated by a student be entirely a new one. The student may be put at the task of rediscovering facts already known; indeed, there may be pedagogic advantages in assigning such problems, in getting at old facts from new angles, in making new combinations, or improvements of technique and precision of measurement. Much of the recent advance of science has come from this very method of increasing the precision of measurement in fields where the main outline of the answer was already known.

A university faculty in science, pure or applied, that restricts itself to teaching only, keeping uptodate simply by reading in periodicals or books the "canned experience" of others, is likely too easily to become mentally fossilized and outofdate. Research in the universities cannot be allowed to die or cease. To continue, however, it must be financed; and the financing, with the universities supported as they are, or are not, must come more and more from industrial support or the subsidizing of research staffs at the universities, unless the governments of the States and the Nation see new light as to the fundamental needs of continual and active research.

As a concrete case, to get a fairly good man to serve as professor of automotive research at a university would require a salary of at least $4,000 a year; assistants, materials, and the like, would cost as much again, and there would be no point in starting and equipping a laboratory for this field of work unless continuity of support were sure for 10 years or more. Such an endowment would, from problems in sight, return to the industry far more than its cost in research results alone, to say nothing of the incalculable value of the supply of trained young men that it would assure. The universities cannot finance the program; with their present resources, they face cuts in staff rather than expansions. What will the industry do?

THOMAS MIDGLEY, JR.[6]:—They had better drop some of the research and spend their time developing research men instead.

PROF. W. E. LAY[7]:—It seems to me that research in American colleges of engineering will be beneficial to the automotive industry, the students, and the faculties of the colleges in three distinct ways. The first benefit is, as Professor Young says, the extending of the frontiers of scientific knowledge.

[5] M.S.A.E.—Professor of experimental engineering, Cornell University, Ithaca, N. Y.

[6] M.S.A.E.—Thomas & Hochwalt Laboratories, Dayton, Ohio.

[7] M.S.A.E.—Associate professor of mechanical engineering, University of Michigan, Ann Arbor, Mich.

The second is not so obvious. I have now on my desk inquiries for young men who can do creditable work in research. In my opinion, research men are born with instincts that, if developed, make them successful. They must be naturally equipped with initiative, a large bump of curiosity, keen powers of observation, ability to analyze what has been observed, and the patience of Job to keep dinging away in the same field until all its possibilities have been exhausted. In addition to training young men, it is becoming more and more the function of the college to help each one to find his proper niche in the scheme of life, to see that the square peg is fitted into a square hole. It is then its business to discover the embryo research man as well as to give him the preliminary training. The only method of discovery that has thus far proved satisfactory is to let students who are interested try for themselves, under the supervision of the instructor, who may act in an advisory capacity only. It often means that if correct results are wanted, the instructor may have to go into the laboratory and repeat part or all the work. It does, however, accomplish the desired result, the discovery of those peculiarly fitted for research work.

The third benefit is also not so obvious but is, nevertheless, important. Research work, especially of the cooperative kind, is one of the few things that may prevent the faculty man from withering and drying up like a fossil. You who have been away from college some 20 years believe you know now what you should have been taught and what the present students should be taught. The whole cry is for thorough training in fundamentals. We believe it, too; so, fundamentals it is. Fundamentals, however, do not change much. The square of 2 and the differential of x^2 were the same 100 years ago as they are now, and will continue to be, barring the rise of a super Einstein. This means that the man who teaches fundamentals must perforce teach the same thing over and over in the same old way. Who can wonder that some of them do dry up and wither in spirit? As the old saying is, "You can lead a horse to water but you cannot make him drink," so, students can be led to high endeavor by an enthusiastic teacher who has experience as well as enthusiasm, but they cannot be driven to work by threats. Close contact between the engineering college faculty and the various industries, especially through cooperative research, will keep alive this enthusiasm, enrich this experience, and make the product of the college doubly satisfactory, a product of young men, with preliminary training and the proper perspective, ready to undergo further training at your hands that will fit them for their proper places in the industry of the future.

F. F. CHANDLER[8]:—You have listened to some discussion today by professors, but I wonder whether you believe in what they say. I was talking to a very prominent automotive engineer this morning; I have talked to him before on this same subject, and will tell you frankly that he thinks research in universities is not worth anything.

I will tell you why he does not think so, and why many others do not think so. In spite of the fact that many of you are university men, you have grown beyond the university stage. You forget that university training is simply a stepping-stone toward success. You have begun to feel, "They do not know so much back there after all." It is true; they do not. In other words, they do not know so much that they cannot know more. But I defy any prominent automotive engineer to prove that research in universities is not worth anything, because that same automotive engineer and every one of you will come to the universities to find the material from which to make research men. The university is your source of supply.

How many of you know that the demands for technical men in this Country in the next 10 years will require an output from the universities of this Country of about 2,000,000 men? There is not sufficient capacity to turn out those men in the combined training forces of all the universities in the United States.

Some of those men must be research men. Universities are taking into consideration the fact that personnel comes into the picture and some universities are paying particular attention to personnel training. Some universities can tell what a man is able to do best; whether he will be a sales engineer, a technical engineer, a research man, a scientist, or what not. The universities that can give the fundamental training which Professor Lay describes and, in addition, can tell what a man is fitted for when he graduates are the ones that will supply the kind of man you want. Professor Lay is correct when he says that, unless you recognize the fact that the universities must be equipped to supply the kind of men you want, they cannot be trained as you desire; and you must help them do it.

I had a conversation today with one of the men in my own company with reference to personal contacts. Our subject was, "Are contacts profitable?" Personally, I like people and he does too. We both like to meet people and to converse with them. The trouble with many of you automotive engineers and other prominent engineers is that you do not recognize that there are honest-to-goodness men in the universities. You have lost your contact with them. You forget that there are men at your Alma Mater who are honest-to-goodness people, who are striving to do something in this world. You never go back. You do not know what they are doing. You would be better for knowing them and they would be better for knowing you. I am glad to know that some of these people are beginning to make known their possibilities. The universities are beginning to recognize that they cannot function as they would like to function, unless they occasionally draw back from industry a man here or there, who has had great contact with humanity and who knows a little better than university people do, what the world requires in the way of men who can do things. The men who are drawn back will broaden the university. The university will then graduate broader men for you.

CHAIRMAN H. C. DICKINSON[9]:—The subject of research in universities is unquestionably one of the utmost importance.

VICE-PRESIDENT J. H. HUNT[10]:—In watching the figures that have been presented, one or two things have occurred to me that seem to be significant. Most of the contributions to university engineering research has come from companies that have more or less of a monopoly. The railroads do not compete with one another in the sense that automobile companies do. A public utility organization does not compete with another public utility organization in the sense that the motor-car companies do. We have a different situation. These industries can contribute money and know that they will get their share. The fact that somebody else gets something from it will be to their advantage rather than their disadvantage.

[8] M.S.A.E.—Chief engineer, Ross Gear & Tool Co., Lafayette, Ind.
[9] M.S.A.E.—Physicist and chief of the division of heat and power, Bureau of Standards, City of Washington.
[10] M.S.A.E.—Chevrolet Motor Co., Detroit.

Take, for example, the installation of air-brake equipment, on which Purdue University expects to finish the test in 1929. Imagine handing an automobile problem over to a university to be finished in 1929! The only kind of problem that an automobile company will send to a university on that basis would be a problem that the National Automobile Chamber of Commerce would support, like the headlighting problem. We could not send an engine problem.

I know of one university that seriously complicates its research work by providing contacts that have to do with patents which are supposed to be developed. When an industry has analyzed a problem to the point at which it knows what it wishes done, it has contributed a large part of the work that is necessary for a patent; and no industry will contribute money to have some one else apply the final touches and get the patent.

I have great sympathy with the ambition of any university to keep uptodate with the most important industry in America today. I think we should contribute. I think the university has a very important selling problem. First, it has a problem of analysis, which is always a problem of selling, a problem of finding out what it can do that no one else will do. If it can find those problems, it will find that the industry will be willing to help it out. The time that any one university man can give to research is so small a part of his time that a university will not get a job to do when the industry can put four men on it and get the result, even if it knows that the time of at least two men will be wasted by so doing. I mean this discussion to be constructive, although it may not have seemed to be so, because I have been pointing out difficulties.

H. M. CRANE[11]:—I wish to support the written discussion of Professor Upton presented by Mr. Midgley. I think that if Mr. Chandler knew what was going on today he would not feel so discouraged about the universities' getting fine support for research work; but Mr. Hunt has pointed out the great difficulty of aiming such research work at the solution of definite pressing problems of the industry. The industry will turn over to the universities for solution problems that probably cannot be solved; and it would just as soon have the universities fail to solve such problems as to fail itself.

I think that if the universities do not get any money from now on, it will be because their method of approach is wrong. If they will go to the industry and say, not that they will solve the problems, but that they will educate the men who, in the future, after they have had experience in the field in addition to the training the university has given them, will solve the problems, they will get all the money they need for research work on an educational basis. In my opinion, that is the only basis on which research work will be a permanent success in the universities.

PROF. H. A. HUEBOTTER[12]:—The activities of the engineering experiment-station at Purdue University fall naturally into three classes. By far the greatest part of the research is of a fundamental nature, which leads to the derivation of data that admit of general application. The study of the carburetion requirements of an engine, and the thermal conductivity of pistons illustrate this kind of investigation.

A second class of research is of a developmental character and includes the testing of apparatus and equipment submitted from outside sources. All commercial tests, laboratory tests of tractors and production carbureters, air-meter construction and calibration, and projects of a similar nature are developmental problems. Such work is largely cooperative with manufacturers whose product is involved.

A third kind of service rendered by the Station lies in its joint interest with the instructional staff in student theses. In the endeavor to broaden the educational facilities open to the student, the curricula of the engineering schools include a student thesis to be conducted during the senior year. This requirement gives the student an opportunity to plan and perform independent experiments and to demonstrate the extent of his research ability. The foundation of a thesis often lies in the bulletins of the engineering experiment-station, and the apparatus used in the major projects is preserved for student use. Series of theses are sometimes extended over a period of years on allied subjects. By this means, ingenuity and aggressiveness in solving new problems are revealed in the laboratory that might not appear in the classroom.

The results of the engineering experiment-station research, then, are (*a*) fundamental data for general application, (*b*) specific information on individual products, and (*c*) guidance and development of student research interest.

CHAIRMAN DICKINSON:—At the beginning of Professor Young's paper he noted the fact that, in the application of scientific knowledge to invention, the United States is outstanding throughout the world, that we are responsible for most of the new developments in engineering lines; but, unfortunately, in the development of the fundamental ideas upon which progress is based, we do not occupy such an enviable position. That is pitifully true. We have not made the great generalizations of the science on which progress rests, such, for instance, as the laws of motion, the law of mass action, the thousands of minor and major generalizations. Consider the mass of information contained in tables and handbooks; the subject matter upon which all basic engineering development depends; those things have not been largely contributed to by this Country when we consider what the world as a whole has done. I believe that contributions in these lines are preeminently the field of universities. If we are to progress in engineering development as we have in the last few years, we must have even more and more in the way of great and minor generalization upon which progress can be based; and even more complete assembling of accurate basic data. Not all those developments have yet come. We shall probably go much farther in the future than in the past. The functions of the universities are to foresee as far as possible the fields in which we need further advances in basic knowledge, the great generalizations on which we can base developments, and to furnish the necessary raw material for further engineering advancement.

[11] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[12] M.S.A.E.—Associate professor of gas engineering, Purdue University, West Lafayette, Ind.

Discussion of Papers at the Annual Meeting

THE discussion following the presentation of five of the papers at the Annual Meeting of the Society that was held at Detroit in January is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication. For the convenience of the members a brief abstract of each paper precedes the discussion so that members who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the February 1927 issue of THE JOURNAL *can do so easily.*

APPLICATIONS OF X-RAYS IN THE AUTOMOTIVE INDUSTRY

BY GEORGE L. CLARK[1], ROBERT H. ABORN[2] AND ELMER W. BRUGMANN[2]

ABSTRACT

A RESUME of X-ray science and experimental results regarding practical applications to the examination of automotive materials is presented by the authors, the main divisions of the subject being (*a*) X-rays; (*b*) radiography, or industrial diagnosis, being an application of the differential absorption of X-rays by matter; (*c*) the ultimate structures of materials; (*d*) metals and alloys, and (*e*) the constitution and structure of other automotive materials in relation to their practical behavior.

The nature and the relationship of X-rays to light, the properties of X-rays which can be utilized practically, and production, including X-ray tubes, are discussed in division (*a*). The detection of imperfections in castings, the development of improved casting-technique by X-rays, the substitution of castings for forgings and X-ray examination of rubber tires, valves and the like are treated in division (*b*).

X-rays and crystals are analyzed in division (*c*) and the information obtainable from X-ray data regarding structural composition includes whether it is crystalline or amorphous; single crystal or aggregate; its crystal lattice-structure and dimensions; purity; chemical identity as to whether compound, mixture, adsorption complex, or solid solution. The data obtainable also apply to grain size, internal strain, uniformity of composition, chemical changes, and the differentiation of good and bad materials.

In division (*d*), the ultimate crystalline structure of the pure metals and the alloys used in the automotive industry, such as brasses, bronzes, steels, alloy high-speed steels, aluminous alloys, and the like, is considered, and the effects of fabrication as determined by X-ray diffraction are discussed in relation to cast metals, to rolled and drawn metals such as hot-rolled and cold-rolled sheets and to heat-treatment and its effect upon preferred orientation of grains, strain and grain size. Some practical studies of commercial automotive metals are cited for cast steel and the X-ray determination of its proper annealing regarding the structure of welds and the comparison of various methods of welding from the viewpoint of X-ray structure, for forming steel such as that suitable for radiator construction and X-ray determination as to whether it is satisfactory or unsatisfactory, for drawing steel-wire, and for case-hardened metals and their wearing qualities. Steel suitable for electrical purposes such as the construction of transformers and the relation of ultimate structures to magnetic hysteresis-loss are considered also, as well as the electrodeposited metals and the determination of desired electrodeposition conditions from X-ray structures. The materials discussed in division (*e*) include rubber; rubber fillers, with particular reference to carbon black; asbestos; the textile fibers such as cotton, flax, ramie, jute, sisal, hemp, rayon, silk, and wool; spark-plug porcelain; lubricants and X-ray indications of the mechanism of lubrication; and paints, varnishes, waxes, shellacs, and similar substances.

In the discussion of the paper, some of the important subjects are the possibilities of X-ray testing of bearings for the purpose of predicting their length of life; the preparation of specimens for X-ray testing; utilization of the fluoroscope for the examination of metals; and the length of time required for obtaining X-ray diagrams of various materials.

THE DISCUSSION

QUESTION:—Considering a bearing, or any part submitted to strain over a period of time, would it be possible after that bearing has been run and, when tested, shows nothing wrong with it, to submit it to X-ray test, record the picture, run the bearing again, submit it to subsequent X-ray test and thus work out a curve showing the life of that bearing before the bearing had actually worn out?

G. L. CLARK:—That can be done. Just now we are making quantitative studies of the interpretation of these radial strain-lines so-called, comparing and making diagrams, and using every method we can bring to bear for the estimation of strain; for example, the turning of cylinders and the measurement of change in dimensions with very fine micrometers.

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[2] Department of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

We have already done what the question suggests, not in the particular case of bearings but in the case of high-pressure oil-still materials. It is really astonishing what can be accomplished, even concerning changes that take place in a short time. We have one section of an oil-still, following it through from the time it was a brand-new piece to the time it bulged out, and showing every step in between. It makes an interesting comparison and there is distinct change. We can plot the results as we did for the single casting which I mentioned. For bearings, I should think it could be done very easily.

QUESTION:—How are specimens prepared for X-ray experimentation as regards thickness, surface and the like?

MR. CLARK:—That is one of the great advantages of X-ray examination, because no preparation is necessary. The X-rays go through. No polished surface is needed; we take the material exactly "as is". The thinner the specimen is, the shorter is the necessary time of exposure. Even then, if we do not wish to cut the specimen up, we can make X-rays penetrate the surface or go as deep underneath the surface as we please. We obtain information about the inside structure. This method is not meant to displace photomicrographic examination, for that has a wide field of application; the X-ray method supplements the data which we get from the photomicrographs. Normally, an X-ray beam penetrates through a piece of material if the material permits it. We carefully cut out the thin piece, properly etching and removing any surface material introduced by the cutting, and then simply place it over the pinhole and get the picture. Where we cannot do that, we allow the X-ray beam to strike the material through a hole in the photographic film; it strikes the object and is reflected back onto the photographic plate. We have taken a number of photographs in that way.

QUESTION:—Can the fluoroscope be used in the examination of metals?

MR. CLARK:—Yes. That is one of the great steps in the development that must be made. Radiographic examination is quite common. What we need is an X-ray tube of high power. The ordinary Coolidge X-ray tube is limited in its power. In Europe, for example, they are using X-ray tubes that run at 130 milliamp.; whereas, the Coolidge tube uses 20 to 30 milliamp. All that is necessary is that we have considerable intensity so that we can see the thing at once on the fluoroscopic screen; with photography, no matter how weak it is, the effect piles up.

Hauser & Mark in Germany were interested to see if the diffraction diagram for stretched rubber came out the instant the rubber was stretched or not. That could not be done by photography. So the investigators went into a perfectly dark room and stayed 4 hr. to get their eyes accustomed to the darkness. They used a powerful tube and set up a screen there. When everything was ready, they stretched the rubber and, instantaneously, the diagram became visible. In our laboratory, we are not only trying to develop these interpretations but also types of apparatus that will permit as wide and flexible use as possible.

CHAIRMAN JOHN YOUNGER[3]:—I was told that, with one of the General Electric machines, 36 hr. is required to get an X-ray picture.

MR. CLARK:—The length of time needed depends upon the material. In working with aluminum some pictures can be taken in a few minutes, other pictures take a few hours. The thicker the specimen is, the longer time it takes. For example, it takes 200 hr. to get a measurement of celluloid, because it is so nearly amorphous.

QUESTION:—Why is the X-ray being used in inspecting fusion welds?

MR. CLARK:—It is being used to make sure that the weld is perfect, adheres well to the other material, and that no blowholes or things of that kind exist. Several companies are using radiographic views.

QUESTION:—What would be the crystal position in the transverse and in the longitudinal direction?

MR. CLARK:—I presume that refers to worked material, such as wires or rolled plates. If we adjust the X-ray beams perpendicular to the direction of working, perpendicular to the axis of the wire, we then obtain the fiber diagram. By that means we ascertain the directional properties. It means that in one direction alone those little grains are all turned so that the same angle is maintained with respect to the X-ray beam and the length of the wire. On the other hand, it does not mean necessarily, of course, that there is this arrangement in all other directions because, if the X-ray beam is parallel to the wire, we find that in this direction there is still random arrangement, as is indicated by concentric rings uniformly intense all around. The same thing is true of rolled metals. If the beam is perpendicular to the direction of rolling, we get the rolling effect; if the beam is parallel, we get none of that fibering effect. Asbestos is fibered in all directions. In the case of metals, working and rolling them and all that sort of thing, it is obvious that there is a wide difference depending upon the directions taken.

QUESTION:—How will the X-ray indicate the amount of cold work either in cold-drawing wire or rolling sheet-metal?

MR. CLARK:—In the first place, you are introducing two things which are somewhat overlapped; one is the arranging of the grains in the preferred way; the other is the introduction of a certain amount of actual distortion. There is a great deal of discussion as to the real interpretation of this. Our symmetrical points on the fiber diagram indicate that lining up; but, in addition, one will often find certain radial streaks running out in all directions. They indicate very perfectly the amount of distortion or the bending of the crystal planes, a stress set-up, introduced by outside working. We are making measurements now which will enable us to give a quantitative evaluation to a given film in terms of the amount of strain or stress introduced. As the specimen is annealed, there is a certain amount of recrystallization and those radial lines disappear. That can all be followed perfectly, but it requires experience. One has to integrate with his eyes to make a new comparison. We are setting up standards all the time by which we can judge just the amount of stress introduced by cold working, and the advantage comes in being able to follow the immediate progress of the heat-treatment process whereby we can remove stress. There lies the greatest possibility of practical application of this type of X-ray examination; that is the controlling of the heat-treatment whereby we can remove or equalize the distortion which is always a source of trouble unless hardness or perhaps tensile strength with very little elasticity are desired.

QUESTION:—Have any attempts been made to utilize X-rays in determining the properties and structure of porcelain?

MR. CLARK:—The studies so far have been to differentiate between the various kinds of ceramics, from the viewpoint of structure. The study of ceramics is just

[3] M.S.A.E.—Publisher and editor, *Automotive Abstracts;* professor of industrial engineering, Ohio State University, Columbus, Ohio.

in its infancy, but the ground work has been well laid.

QUESTION:—Have any data on fatigue-test specimens been obtained? For instance, does a specimen having been subjected to A lb. per sq. in. and 100,000,000 reversals have any relation to one of the same material that has been subjected to 2 A lb. per sq. in. and say 25,000,000 reversals?

MR. CLARK:—That experiment is being made now but no data are available yet. The experiment is being made with some of the aluminum alloys, subjecting them to comparative stresses and to rapid vibratory bending and all sorts of stresses of that kind to see just what actually does occur.

QUESTION:—In tests made on rubber, have you ever examined a given compound under different degrees of vulcanization or the same compound under different periods of age?

MR. CLARK:—That again is a subject which is more or less in its infancy. It has been but comparatively few months since we have understood or known that we can get this characteristic diagram for rubber. Anything you do to rubber certainly does have an effect upon the structure. You can get a diagram even on vulcanized rubber. In fact we could take soluble fractions and insoluble fractions, all those things give characteristic results. The lines of demarcation unfortunately are not so sharp as in the case of metals, because here we are dealing with very complicated colloidal systems.

We can theorize upon the subject but it is impossible to say what the exact effect of vulcanization may be or exactly what takes place. There is fairly good X-ray evidence, but we shall have to go back again and consider rather seriously the physical theory of vulcanization. We know the chemical theory. The chemical combination has held the boards for 2 or 3 years at least, but X-ray evidence indicates that we must go back and survey very critically again the idea of physical combination, solid solution and so on. The evidence is very strong in that respect, but much of this work still remains to be done.

QUESTION:—What information does the X-ray give regarding the mechanism of fatigue failure of metals? Does magnetized steel exhibit typical fiber-diagrams?

MR. CLARK:—Steel, when it is magnetized, or magnetized and non-magnetized, apparently gives us no difference in the X-ray diagram; that is, considering the same specimen. We have tried it several times; apparently, magnetization goes down even on beyond the ultimate crystal to the atoms themselves. Magnetism is a very serious and a very difficult problem. We are trying to line molecules up in strong electric fields and see if we can line them up by this outside force. If we can line them up, obviously they will give one of these diagrams. The results so far indicate exactly what takes place with an outside force to line molecules up.

QUESTION:—For general automobile work approximately what does an X-ray outfit cost? How much does each photograph cost?

MR. CLARK:—The General Electric diffraction outfit costs from $2,500 to $2,800 complete. An X-ray equipment is an expensive apparatus and perhaps a few laboratories can utilize it better than to have every company try to install an X-ray laboratory; but, so long as we use it as a research tool in developing the technique, it is really cheap. One of these X-ray exposures does not represent a very great expense. It is simply a matter of the amount of power expended in the X-ray tube and certain overhead allowed for the apparatus. The more exposures one takes the less expensive each one becomes. Some X-ray operators in this Country charge a high price for a single exposure, which is to be expected. But for industrial purposes and for examining good and bad material, it is not a prohibitive price by any means.

QUESTION:—Is a different structure disclosed by X-rays in a metal stretched by tension than in the same metal drawn through a die and thus compressed laterally while extended longitudinally?

MR. CLARK:—I will answer that in a rather general way by saying that any combination of working processes makes itself known immediately. Sometimes you can have a combination of two or three fabricating effects upon the same diagram. Of course there are certain inherent tendencies in iron crystals, or tungsten crystals, for example, which make them turn in a perfectly definite way. If you apply a deforming force, for example, a crystal will turn differently depending on whether it is rolled or drawn. If you combine the two you get a combination of effects, or the result, I might say, of complicated stresses which are applied. But, in general, I think it is possible to identify any fabricating process or any combination of them.

QUESTION:—Is it possible by means of X-rays to discriminate between the various kinds of non-metallic inclusions in steel?

MR. CLARK:—Dr. H. H. Lester, at the Watertown Arsenal, perhaps has done more than anyone else. Many people have asked him from time to time to put down on paper criteria for various types of imperfections. He has refused to do that because so much depends on the angle of the fault relative to the photographic plate or fluoroscope. He has had the experience whereby he can look at a given radiographic picture and tell immediately what was photographed, what is the matter with it and what ought to be done to it. He is actually able to do this from his experience. It is hard to specify interpretation as a hard and fast rule.

NEW GENERAL MOTORS INSTITUTE OF TECHNOLOGY

BY ALBERT SOBEY[1]

ABSTRACT

THE new Institute of Technology now being established in Flint, Mich., by the General Motors Corporation represents a movement to provide definitely for the development of the man-power for the Corporation's world-wide organization. Changes in industrial organization and methods during the last generation have lessened greatly the opportunity for the development of employes in the regular processes of industry. As a result, training and development of industrial man-power have become one of the foremost problems of industry. Organized research, experiment and development in the field of training of skill and intelligence of personnel to correlate it with and make experience in the shop systematic and effective is needed for the human phases of industry to correspond with the coop-

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erative effort of the specialized research, design and experimental departments with the production departments in manufacturing organizations.

Training that can best be given in the Institute will be centralized there. The Institute will serve as a central clearing-house for methods, outlines of training courses and the like for training that can best be given at the local units of the Corporation. It will receive reports of progress and suggestions for improvement which will be analyzed and made available to all units. Thus it will serve as a centralizer and coordinator of the cooperative effort of all the units in the field of personnel development.

The program of the new Institute will be built upon that evolved for Flint units by the Flint Institute of Technology during the last 7 years. This provides spare-time courses for present employes and short special full-time training and cooperative courses for incoming employes. The Buick Authorized-Service Course is illustrative of the short full-time training. It is a 12-week course intended to prepare men to become specialists in Buick service. Two cooperative courses are provided, one a 2-year Technical Trades Course for developing tool and die-makers and the other a 4-year Cooperative Engineering Course of college grade for developing junior executives. The work of the new institution should bring material economic and social results in view of the results already obtained in Flint. The social significance of 4 per cent of the City's industrial employes using their spare time during the last term of the Institute in 1926 for personal development is obvious, as is also the value of this as regards industrial morale. Hundreds of men are working their way upward in Flint industries through this program. Results of other phases of the program are equally satisfactory.

The discussion, all of which was oral, brings out (*a*) the need of a system and an organization in the factory for training young college men; (*b*) that if the automotive industry is to secure the kind of trained men it wants from colleges it must make contact with the educational institutions as the electrical and locomotive industries have done and influence the courses of study; (*c*) that the cooperative training plan of alternate periods of study in the university and work in the factory is proving successful and should be watched; (*d*) that the community apprenticeship plan is working well in some places; (*e*) that extremes in training should be avoided or management may lose contact with its working forces; (*f*) that educational institutions need the industry's financial help; and (*g*) that the largest field in which trained men is needed is the maintenance field.

A committee appointed by the National Automobile Chamber of Commerce has prepared a standard course for automotive schools and the National Automobile Dealers Association is considering the advisability of its putting the plan into effect and systematically supervising the schools that agree to adopt such a course of instruction.

THE DISCUSSION

JOHN YOUNGER[5]:—I am not one who feels that the General Motors organization should not go into the school business. I think it should, because the organization has about 150,000 employes, I believe, and that number, on the basis of one employe to an average family of four persons, represents a population of 600,000. When one thinks of a city with a population of 600,000, especially a city dependent upon one industry, the automotive industry, it is realized that it provides ample room and an ideal opportunity for an institution such as Mr. Sobey has described. I think wonderful opportunities exist in Flint because the Institute is able to concentrate. I hope it will not shut the doors to graduates of other institutions. At Ohio State University we are proud of the fact that Past-President Kettering and President Hunt of this Society are both graduates of that institution, and I should like to see the General Motors Institute open its doors to Cornell, Adelbert, Ohio State, and other universities.

The automotive industry has not been going to the colleges for its men. It may not find at once the men it needs when it goes to them, because the universities must be very broad in their training. They train men for ceramics, civil engineering, metallurgical engineering, and all the other branches of industry. But if the automotive industry makes a practice of going to the universities, and talking with the faculties, it will eventually secure the trained men it wants. This is being done by the Western Electric, General Electric and Westinghouse companies. The automotive industries can do the same and in time the universities will evolve a series of courses and a personnel that will meet the wants of the industry.

ALBERT SOBEY:—This matter of college graduates has been handled through the industrial relations department in the General Motors Corporation, which I understand is paying more attention to college graduates than ever before.

[5] M.S.A.E.—President and editor, *Automotive Abstracts;* professor of industrial engineering, Ohio State University, Columbus, Ohio.

[6] St. Louis.

H. A. FROMMELT[6]:—One of the surest ways of making a failure in taking college graduates into a plant and attempting to give them a training is to do it without any system or supervision. I had some very definite experience along this line 8 or 10 years ago at a cooperative engineering-school, which was operating and is now operating on exactly the same basis as Dean Schneider's school did in Cincinnati. It made connections with 25 or 30 leading industries and had young men in training in the plants. Four or five years later an intensive apprenticeship-training program was started in these plants. It was very evident, upon going into these plants to inaugurate the training program, that the college-graduate plan failed utterly and what remained of it was retained solely through sheer power of the individual college graduates to hold on. They were in no different position than any other young man who was taken into the plant, placed in a department and told in effect,

> Now you sink or swim. We are not attempting to give you any specific training. Go to work in there and get what experience you can out of it. Let us know how you like it.

I do not think those who survived were the kind of material one would want to deal with later. They did not have enough pluck to say at the end of a month or 2 months, "This program does not amount to anything and I am not going to stay." But with the inauguration of an apprentice-training program, a system for taking care of apprentices, generally including the college graduates, was included. The college-graduate part of the plan developed until to-day it forms a vital and essential part of this training program.

INDUSTRY SHOULD HAVE 50,000 APPRENTICES

Organization and supervision are quite as necessary for the college graduate as for the grade-school and high-school graduate. Fifty thousand apprentices should be at work in the automotive industry at present. From experience we know that at least 10 per cent, or 5000,

should be college graduates. The best way to get the 5000 is to organize a training program in the plant and put in personnel to systematize and supervise these programs. It will not be necessary to send questionnaires to the colleges to get the young men; they will come to the plant and will stay and make the kind of personnel that is wanted in the plant. One should not expect the college man to come fully equipped, a finished product, qualified to fill a specific place in the organization at once. He must complete his industrial education just as the grade-school and high-school boys do. Unless a system is set up to help in this, the program will fail, just as it is failing for the trade apprenticeships.

CHAIRMAN LOUIS RUTHENBURG[7]:—Apparently we need some definitions to clarify this discussion. Just as procurement and processing of production materials are distinct functions which should not be confused, so industrial education, as such, is not to be confused with the closely related but distinctly different function of establishing contact with sources of supply and obtaining the partially processed human material which we hope to turn into a more nearly finished product by industrial education. The function of supplying human material of suitable characteristics is largely in the hands of our personnel and employment divisions. Mr. Dougherty, have you something to say about this phase of the subject?

COOPERATIVE-ENGINEERING COURSES PRODUCING RESULTS

N. F. DOUGHERTY[8]:—I am surprised that this learned and trained body of automotive engineers are not more interested in the question of education and training men. The General Motors constituent companies took more than 100 college graduates in 1926. Our divisions have worked out a very good training course for the men they have taken in.

I talked with a graduate of the University of Michigan who came into the office for a job, and told him that we were trying to get some young men in the foundry as well as in the other production departments. I explained the work to him and told him how dirty it was and the class of labor with which he would have to work there. He said he wanted to look it over, and after going through the foundry he took the job. Such men are put in the regular production lines. I do not agree altogether with the methods in some of the training courses in other industries nor that the number of men they are taking is right. Not many of the college men are being put into the production lines in some industries.

In addition to the 100 college graduates, we have 160 pairs of cooperative students; 40 from Dayton, 40 from Antioch and 80 from Mr. Sobey's school. This cooperative-education movement is one that the colleges must study. The Michigan State College is considering it, but some members of the faculty are opposed to it. Syracuse University is considering it, but has not yet adopted it, although I think it will do so. Some of the executives in the automotive industry would still prefer to take the college graduate. I do not think we shall ever reach the point where we will follow a single method. We are not concerned primarily about apprentices or cooperative-engineering college students; we are trying to find the individual boy and man who is to do the specific work we want done. No single policy of employing a definite kind of trained man should be adopted.

This cooperative plan of education certainly is working well. One of our works managers told me he has a considerable number of cooperative students and has had them for several years. He said that if he could get all his students from Cincinnati he would not bother about graduates from any other college, because by the time these boys have graduated they have found their places.

I think some thought should be given to the apprenticeship plan, which is also important. Members of the Society could do much to aid this movement. Anderson, Ind.; Dayton, Ohio; Lansing and Pontiac, Mich.; and a number of other cities have cooperative-apprentice courses in their high schools. Tenth-grade boys are selected. They spend 2 weeks on the job and 2 weeks in school alternately. After they graduate from school they spend 1 more year in the factory. I think Purdue University will accept Anderson graduates in its evening course.

This is a big question and industry in general is greatly interested in it. I do not know that the automotive industry is doing its part. We are not doing all we should do until we secure the type of men we need.

MUST INFLUENCE COURSES OF STUDY

H. M. JACKLIN[9]:—The automotive industry wants to secure men trained along certain lines and should go about obtaining this result. Every year the colleges are visited by representatives from the electrical and locomotive companies and other industries that are foreign to the automotive industry. Ohio State University was visited last year by three representatives from the automotive industry. These other industries are actually influencing the courses of study. They have done so for years and will continue to do so. They are "on the job" and automotive men must get "on the job" too.

H. K. CUMMINGS[10]:—Another way in which engineering-school contacts can be made is through the adoption by certain engineering schools of the plan of a 5-year course. This is intermediate between the old way of graduating the student before he has had any direct contact with industry and the cooperative plan of alternate brief periods in school and in industry. Under the 5-year plan the student spends 2 or 3 years in the engineering school, then goes into the industry for 15 months, and afterward returns to college to finish his course. When he completes his final year he usually can be placed in the industry to better advantage than the man who has only school training. This plan has been applied with great success in connection with some industries, particularly the electrical industries.

SHOULD AVOID EXTREMES IN TRAINING

G. A. SCHREIBER[11]:—An old saying is that a good man cannot be held down. Neither can a good boy. While spending about half a year in Europe recently, I noticed a tendency there that has almost wrecked a number of industries. Too much of the military aspect prevails now in certain European industries. Ex-officers and some mere college graduates are trying to dictate what shall be done in certain industries and as a result the management of the companies has lost almost all contact with its working forces. I hope we shall not follow in these footsteps by so arranging the training that certain department heads shall always be doctors of engineering and so on. We should avoid going to extremes in the training of our forces and investigate, rather, how some of our present leaders in the industry reached their goal.

About 17 years ago a young foreman came to Detroit

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[8] Director of industrial relations, General Motors Corporation, Detroit.

[9] M.S.A.E.—Professor of automotive engineering, Ohio State University, Columbus, Ohio.

[10] Associate physicist, Bureau of Standards, City of Washington.

[11] M.S.A.E.—Consulting engineer, Detroit.

from Pittsburgh, where he had received 4 years of good training with the Westinghouse Electric & Mfg. Co. The first job he found in Detroit was in a small motor-car plant. He had gone to high school but never went to a university; however, he had an excellent shop training and was always anxious to learn more. By years of hard work and fair play with his co-workers, he recently became one of the highest-paid officials of the Chrysler organization. He reached this position step by step, enlisting the cooperation of his co-workers in the organization whenever possible instead of bringing in a new team from outside.

Only a few years ago the White Motor Co. also found a successful solution of this training problem. One of the younger Whites employed a good professor to start a little shop-school. Some of the best graduates that could be found at Harvard and Yale were brought as apprentices to work in the plant and they later entered classes for shopmen and foremen. They had to wear overalls for a year or two at least, and worked as die-makers and tool-makers and as production and time-study men.

In less than a year one of 12 of these college graduates was the right-hand man in the production engineer's office. Another, who was a good mathematician, became one of the best known of the boys in the time-study department, after working around the shop for a year; he had found his place in the big organization. A third man, who had worked in the summers of his college years, was good at technical copy-work. With the experience he had gained in technical advertising and statistical work in the summers and a year of shop experience, he was able to help the advertising manager in the writing of operators' handbooks, technical matter, advertising, and sales manuals. Others worked themselves up quickly in the service and transportation fields. Such all-around education is required now, I think, to bring about the desired results for such men as we need so badly these days for the production, selling and servicing of motor-vehicles in the best possible way.

CHAIRMAN RUTHENBURG:—As industries build their own educational routes they will reach out and establish the contacts that are desired. Under the method used by the electrical companies in inducting students, the students go through a definite graduate-engineering-apprentice course and are then distributed to various branches of technical and sales work. By establishing this method of apprenticeship the companies have built a track which the students can follow from the university to the industry.

How Can Misfits Be Prevented?

EARL E. EBY[12]:—I should like to ask a question that bears on the differentiation between the trade school and the regular 4-year engineering-course as it concerns a young man who possibly has not definitely decided that he wants to take up any particular phase of engineering. Suppose we should take such a young man into our factory or that he went to a cooperative school to pursue his engineering course and then should be automatically inducted into the automotive industry. Possibly he would not be fitted for this industry; he might be more successful in some other line. Is not a boy who attends a cooperative course, usually 6 years in length, compelled to decide immediately after he graduates from high school what engineering field he is going to enter, whereas the student who takes a general 4-year engineering-course can possibly make up his mind as late as his junior or senior year?

MR. SOBEY:—The adjustment of young people to the fields of livelihood for which they are best adapted is a serious problem and becomes more serious in connection with the spare-time classes and programs which include men 35 and 40 years of age. So far as our own course in cooperative engineering is concerned, we are aiming primarily to select for that course young men whose general background and aptitude seem to fit them for the kinds of work embraced. Our aim is to build up these men by combining with the fundamental training given during the school periods a directed practical experience during the cooperative work period. This work program is made so flexible that it can be adapted to meet the natural aptitudes of the student as he develops and thus becomes an aid to him in finding himself. The following case illustrates this point:

A young man who, it seemed to me, was of the type that would make a leader in a certain class of work, entered our cooperative course much interested, and started the cooperative work to which he was assigned with enthusiasm 3 years ago last September. After about 4 or 5 months he said he did not like the work in the shop and was not at all satisfied. I told him that we wanted to give him a machine-repair training and other experience that would lay a good foundation for the kind of work for which he was best fitted and that the contacts he would make with the men in the shop would be valuable. He consented to remain the rest of the year and we studied him all that year. Much to my surprise he turned out to be very analytical and thought things through carefully, so we put him in the research department.

Another boy of much the same type was paired with him and they have been working in the department since that time. His superior told me last summer that he is coming along wonderfully and that he thought the young man knew more about the work to which he was assigned in the department than anyone else, himself included. This illustrates how cooperative experience in the shop will help a young man to find himself very quickly.

Schools Need Industry's Financial Help

CHARLES F. LOEW[13]:—I think the cooperative school is one of the biggest factors in training young men properly for the industry. Some years ago the Young Men's Christian Association in Cleveland started a cooperative school known as the Cleveland School of Technology. A few instructors in the Case School and Western Reserve University gave part of their time to instruction in the evening classes, but the boys did not have sufficient instruction. In our plant we had four boys, two alternating with two others and attending the school. They liked it because it gave them the training that they could not get otherwise, but I think all eventually gave up their course because of lack of proper instruction in fundamentals due to insufficient funds of the school.

If we in the manufacturing industries will consider the needs of the classroom and make donations or endowments to help the schools, I believe the results will be better. We are willing enough to take these young men, put them into our plants and give them our training, but we do not go farther back to see what the school is doing and to help it.

Father Wanted for Standard Training-Course

H. R. COBLEIGH[14]:—The big field in which we need automobile mechanics is the maintenance field. Someone has estimated that about $6,000,000,000 is spent an-

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[13] M.S.A.E.—Vice-president, Loew Mfg. Co., Cleveland.
[14] M.S.A.E.—Secretary of service, National Automobile Chamber of Commerce, New York City.

nually on maintenance and $2,000,000,000 on production. The training of men for production is much simpler than for maintenance, because the organizations are larger units. Upward of 80,000 repair-shops are spread all over the country. Obviously it is out of the question, with such a large number of shops, to do anything with the apprenticeship plan as has been done in the foundry trade, nor is it possible to send any considerable number of the men required to the Flint Institute to be trained. The work being done in Cincinnati and Cleveland by the cooperation of the public schools with organizations in the automotive industry in these cities would go far toward solving the problem if extended to enough cities well distributed geographically.

Two years ago Fred C. Smith reported for the mechanics training committee appointed by the service division of the National Automobile Chamber of Commerce that 90,000 new men a year are taken into the maintenance field and that only 20,000 of these have had any previous training. This gives some idea of the problem. Nearly 80 per cent of the men entering this business are learning it by the pick-up method. What is needed is a means of giving them a better start through some preparatory education so that they can be broken in more quickly when they go into the repair shop. As a help toward the solution this committee prepared a standard course for automotive schools to bring about greater uniformity in their product. To accomplish the desired object the schools that agree to give the standard course must at least be inspected to see that they do so. The directors of the National Automobile Chamber of Commerce felt that it would be more in order for the National Automobile Dealers Association to function in this capacity, and the plan is now under consideration.

DETONATION CHARACTERISTICS OF PETROLEUM MOTOR-FUELS

BY SAMUEL P. MARLEY[15], DONALD R. STEVENS[16] AND W. A. GRUSE[17]

ABSTRACT

AN examination for detonating qualities of 18 petroleum gasolines was made by the authors, the methods used being those of direct engine-tests and of chemical analysis. A single-cylinder lighting-plant engine, suitably modified, and a direct-reading detonation-indicator were utilized and they are described. The method of Morrell and Egloff was followed in the chemical analysis. This consists in determining the proportions of paraffins, naphthenes, unsaturated and aromatic hydrocarbons and calculating the aromatic equivalence of the hydrocarbons so found by the use of data compiled by Ricardo on the relative knock-reducing tendency of unsaturated hydrocarbons, naphthenes and aromatic hydrocarbons. These data indicate an equivalence expressed by the ratio 5 to 4 to 1.

Experiments were made in which a constant proportion of one hydrocarbon of each class was added to a gasoline, and the detonating tendency of the resulting mixture was determined by engine test. Use of two gasolines as base fuels and a system of inter-comparisons gave results indicating, for the particular experimental conditions and for the hydrocarbons used an equivalence indicated by the ratio 2 to 2 to 1. The examination by engine test involved comparing each gasoline with mixtures of a standard gasoline and benzene or kerosene. The mixture equivalent to each gasoline gave the so-called benzol equivalent. The equivalent was determined for each gasoline against two standard fuels, one a straight-run Mid-Continent gasoline and the other a good average motor-gasoline. It is pointed out that the degree of correlation between results by engine test and results by chemical analysis will vary with the quality of the standard fuel employed. In general, the benzol equivalents calculated from chemical analysis did not agree satisfactorily with those found by engine test. In the absence of published data on the influence of volatility of gasoline fractions on detonating tendency, a straight-run Mid-Continent gasoline was fractionated into 18-deg. fahr. fractions, and succeeding fractions were then added to the original gasoline in fixed proportions. The distillation data and detonating tendencies of the mixtures are given. The work confirms the general belief that detonating tendency increases with rise in boiling-point. The indications of the work are that petroleum gasolines of satisfactory antiknock value are available, and that the detonating tendency of gasolines is best determined by direct engine-test.

Important written contributions on the relation of volatility to detonation, on comparison of detonation, characteristics and on combustion experiments, appear in the discussion.

THE DISCUSSION

J. B. HILL[18]:—In the paper under discussion, the authors have brought out the relation of volatility to detonating tendency. I confirm and supplement the information and conclusions presented therein by stating the results of some work done in our laboratory.

In this work, a sample of straight-run Mid-Continent gasoline, with 50 per cent distilled off at 284 deg. fahr., was subjected to rough fractional distillation. The cuts were tested by the American Society for Testing Materials's method of distillation and by engine test for detonation. The results of the engine test were recorded as the number of pounds per square inch compression-pressure necessary to produce detonation with the test sample alone, under the conditions of the test.

The detonation results, plotted against the 50-per cent point on the distillation curve, gave a perfectly smooth curve from which the values shown in Table 1 are taken. The "benzol equivalents" are the percentage of benzol which must be contained in a mixture with the original gasoline to equal the sample under test. The data shown are on cuts of about 35-deg. fahr. distillation-range.

A series of tests was also made in which the same 50-per cent point was maintained, but the cut widened in successive stages from a total range of 35 deg. fahr. to a range of 270 deg. fahr., the end-point changing from 327 to 462 deg. fahr. The detonation results on all these samples were identical. The indicated conclusion is that

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[17] M.S.A.E.—Director of petroleum investigations and industrial research fellow, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh.

[18] M.S.A.E.—Chief research chemist, Atlantic Refining Co., Philadelphia.

TABLE 1—BENZOL EQUIVALENTS

50-Per Cent Distillation-Point, Deg. Fahr.	Detonation Pressure, Lb. Per Sq. In.	Benzol Equivalent, Per Cent
212	104.0	35
248	97.0	20
284	92.0	0
320	88.5	— 30[a]
356	86.0	..
392	84.5	..
428	83.0	..

[a] Extrapolated valuation.

the volatility index affecting detonation is not the end-point but, as has been suggested, the intermediate range and specifically the 50-per cent point.

The authors point out the irregularities in the detonation tests of successive fractions and suggest a concentration of antiknock compounds in certain fractions. Work which we have done on very careful fractionations of gasoline, resulting in cuts of a total distillation-range of about 5 deg. fahr.,[19] fully bears out this point. For example, a cut from California gasoline with a 50-per cent point of 284 deg. fahr. was equivalent in detonation to our straight-run Mid-Continent standard fuel; whereas, a later fraction from the same gasoline with a 50-per cent point of 271 deg. fahr. was equivalent to a 40-60 blend of benzol with the standard fuel.

Comparison of Detonation Characteristics

W. F. Faragher[20]:—To compare the detonation characteristics of motor fuels as determined by engine test and by chemical analysis, motor fuels have been tested in large numbers, during several months, by our gasoline-engine method and by the laboratory method developed by Egloff and Morrell[21]. The modified Delco lighting-plant and accessories used, as well as the method of operation, are described in the paper on Apparatus and Method for Rating Motor Fuels in the order of Detonation[22], by W. F. Faragher and W. H. Hubner.

Typical data are presented in Table 2 and Fig. 1. Lack of agreement between the two methods is indicated in a large percentage of the tests. Agreement is not to be expected, of course, for those fuels that contain tetraethyl lead. Casing-head blends, benzol blends and motor fuels from California crudes also show wide differences.

A relationship between the analytical data and the results with the engine was suggested by Jesse L. Essex of our laboratory. It is presented in Fig. 2, which shows the sum of the naphthene hydrocarbons and the aromatic hydrocarbons, as determined by the analytical method,

[19] See *Industrial and Engineering Chemistry*, January, 1927, p. 128.

[20] Director of research laboratory, Universal Oil Products Co., Chicago.

[21] See *Industrial and Engineering Chemistry*, April, 1926, p. 354.

[22] See THE JOURNAL, March, 1927, p. 405.

TABLE 2—TYPICAL DATA FOR THE DETERMINATION OF DETONATION CHARACTERISTICS.

Fuel No.	Engine Test, Percentage of Benzene in Reference Fuel B	Aromatic Hydrocarbon Equivalent Ratio			Hydrocarbons				Specific Gravity, American Petroleum Institute Deg.	Initial Boiling-Point, Deg. Fahr.	End-Point, Deg. Fahr.
		Ratio 0-1/5-1-1/4	Ratio 0-0-1-1	Ratio 0-1/2-1-1/2	Unsaturated	Aromatic	Naphthene	Paraffin			
0	0	8.4	16.6	12.3	2.9	4.9	11.7	80.5	58.9	146	426
9	8	9.4	22.7	14.9	3.0	4.1	18.6	74.3	58.2	127	431
28	12	10.5	23.0	16.0	3.5	5.4	17.6	73.5	57.5	128	433
8	15	17.5	27.9	23.2	6.1	12.4	15.5	66.0	57.9	107	424
10	18	16.3	28.0	22.5	6.1	10.8	17.2	65.9	57.1	115	434
13	20	17.4	28.1	23.9	7.1	12.6	15.5	64.8	57.4	112	434
15	25	10.5	28.5	17.7	3.2	3.7	24.8	68.2	61.1	103	401
31	25	19.7	27.0	26.3	11.2	14.3	12.7	61.8	56.5	96	436
34	28	18.6	27.4	25.4	10.5	12.8	14.6	67.1	58.9	99	432
35	28	23.4	28.3	30.5	14.9	17.8	10.5	56.8	58.0	99	434
36	30	28.0	33.7	33.5	9.7	23.5	10.2	56.6	58.3	96	422
37	33	16.6	25.4	21.7	6.0	12.0	13.4	68.6	60.5	108	423
32	33	18.4	25.4	27.3	18.0	11.2	14.2	56.6	64.4	98	391
19	37	30.2	33.8	37.0	15.3	24.8	9.0	50.9	56.2	100	431
14	37	16.8	29.6	24.7	9.9	9.8	19.8	60.5	61.3	118	397
12	37	14.1	19.9	19.4	9.3	9.6	10.3	70.8	59.6	110	404
1	40	83.4	85.0	85.0	3.0	82.0	3.0	12.0	44.3	160	412
16	40	30.2	38.0	39.0	17.0	23.0	15.0	45.0	59.8	100	397
17	40	24.1	31.7	32.6	16.2	17.3	14.4	52.1	61.9	90	405
18	40	24.1	31.1	32.1	16.3	17.7	12.4	53.6	61.9	86	402
4	40	49.2	58.4	53.5	3.4	45.2	13.2	38.2	48.6	147	426
26	40	27.3	34.0	35.3	15.6	20.9	13.1	50.4	53.5	110	436
3	42	57.8	64.9	61.3	2.9	54.6	10.3	32.2	57.3	150	422
29	43	8.7	32.4	17.7	2.9	0.0	32.4	64.7	64.5	128	370
5	43	5.0	5.4	6.0	2.3	4.2	1.2	92.3	60.9	140	432
30	47	13.8	40.0	23.0	1.3	4.6	35.4	58.7	56.2	115	396
11	48	21.2	37.3	30.4	10.3	13.0	24.3	52.4	57.4	98	422
33	48	35.6	43.6	43.2	13.4	29.3	14.3	43.0	53.1	123	419
20	48	12.1	39.8	22.4	2.8	2.1	37.7	57.4	55.7	148	419
2	50	75.2	78.5	77.2	2.2	73.6	4.9	19.3	43.7	168	410
24	50	26.9	38.4	37.1	17.3	18.4	20.0	44.3	53.5	114	438
6	55	8.4	16.6	12.2	2.9	4.9	11.7	80.5	58.9	146	426
27	57	33.1	38.8	42.4	20.1	25.8	13.0	41.1	50.1	170	448
23	58	13.8	43.8	25.1	3.4	2.9	40.9	52.8	56.2	122	430
7	60	3.8	12.9	8.0	3.0	0.0	12.9	84.1	59.0	117	458
21	62	11.4	43.9	23.1	2.3	0.0	43.9	53.8	56.5	126	422
22	62	17.8	48.1	27.9	2.6	5.0	43.1	49.3	53.0	144	415
25	65	25.2	33.8	35.3	19.6	17.1	16.7	46.6	50.5	120	437
38	78	21.9	58.6	36.6	6.6	8.0	50.6	34.8	51.5	105	431
39	88	34.6	63.6	49.1	13.1	21.4	42.2	21.3	50.8	86	420

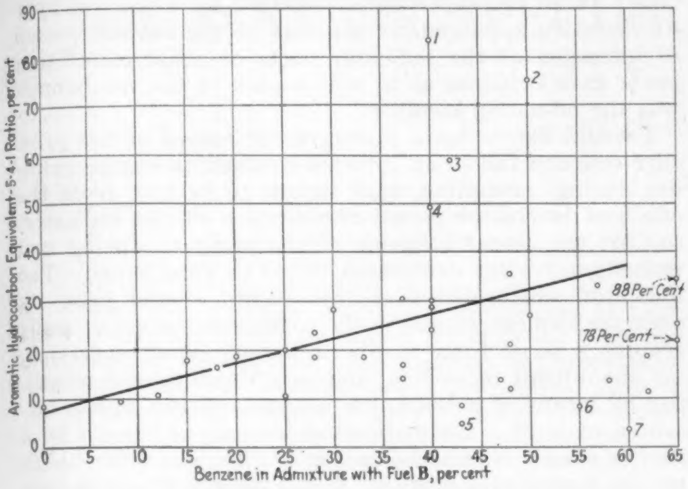

FIG. 1—CHEMICAL ANALYSIS VERSUS ENGINE TESTS
Lack of Agreement between the Two Methods Is Indicated in a Large Percentage of the Tests

as a function of the percentage of benzene in the blends that were shown by the engine to match the fuels. Obviously, the factors for calculating the aromatic-hydrocarbon equivalent are 0, 0, 1, and 1 for paraffin, olefine, aromatic, and naphthene hydrocarbons, rather than 0, 1/5, 1 and 1/4, respectively, the factors derived by Egloff and Morrell from the data of Ricardo. A comparison of Figs. 1 and 2 shows that the better agreement is obtained by using the first set of factors.

We do not propose that this better agreement justifies the use of the analytical method for unknown fuels. It seems reasonable to conclude, however, that other factors can be determined that will make the agreement even better. The analytical method still has a field of usefulness and should be made as good as possible. Fuels made in a refinery at different times from the same or similar crudes by similar processes have been evaluated satisfactorily by the analytical method. It is fully recognized, however, that the engine is the necessary equipment for testing fuels of unknown origin.

The determination of the proper factors was undertaken by Marley, Stevens, and Gruse. However, it was wholly improbable that the method used by them could lead to the correct values. A single hydrocarbon of an homologous series hardly can be expected to have the average value of the hydrocarbons of that series in a motor fuel. Great differences between the members of all the series have been found by many experimenters.

Fig. 3 shows the values calculated by using the Marley-Stevens-Gruse factors for the fuels represented in Figs. 1 and 2 and in Table 2. Little improvement is effected over the use of the factors of Egloff and Morrell; and the agreement is not as good as that obtained when the factors of Fig. 2 are used.

The separation of the hydrocarbons of each homologous series from motor fuels should prove the feasibility of using a single factor. This work is now in progress in our laboratories.

R. E. WILSON[23]:—I am glad that both Dr. Marley and Dr. Faragher said that they did not recommend analytical methods as a substitute for engine tests. I think it is necessary to use engine tests to determine the relative values of different fuels. You are likely to be misled if you use the reverse process. No better proof need be cited than the three different ratios, 5 to 4 to 1, 2 to 2 to 1 and 0 to 1 to 1, given by these different authors for the relative values of these types of hydrocarbons. That shows something of the uncertainty.

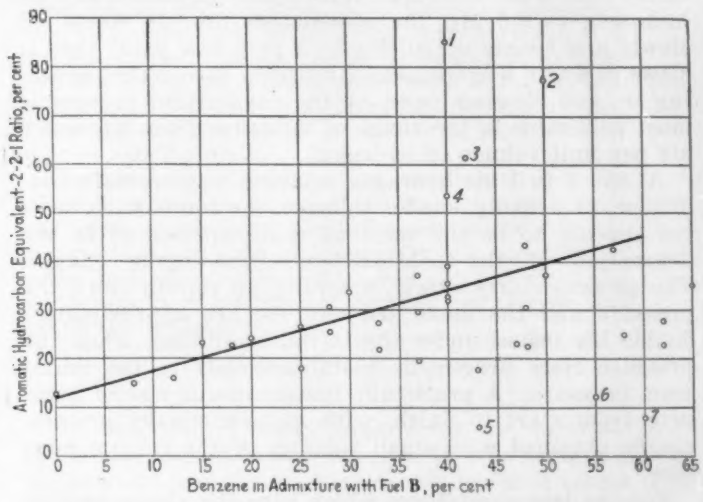

FIG. 3—CALCULATED VALUES
The Values Were Calculated by Using the Marley-Stevens-Gruse Factors for the Fuels Represented in Figs. 1 and 2. Little Improvement Is Effected Over the Use of the Factors of Egloff and Morrell. and the Agreement Is Not As Good As That Obtained When the Factors of Fig. 2 Are Used

There is just one other precaution. I am afraid a paper that states the exact percentages of the different types of hydrocarbons might be taken too seriously by non-chemists, although its limitations are fully appreciated by chemists. Such an analysis is not the same as one for inorganic material; it is based on differential solubilities and is not by any means a hard and fast separation. In fact, I know of three published methods that will give results varying from 3 to 25 per cent for the percentage of aromatic hydrocarbons in certain gasolines. I am not saying which method I think is right but merely wish to emphasize the fact that these figures are really qualitative and should not be taken as quantitative.

Another great difference is between the low-boiling and the high-boiling members of the same series. One may find as much difference between them as between members of two different series so that the splitting up of a fuel into three or four classes of hydrocarbons does not have the significance that might be assumed.

COMBUSTION EXPERIMENTS

PROF. L. C. LICHTY[24]:—Several years ago Professor Wohlenberg and I started some experiments on the combustion of hydrogen. The object of these experiments

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[24] Assistant professor of mechanical engineering, Sheffield Scientific School, Yale University, New Haven, Conn.

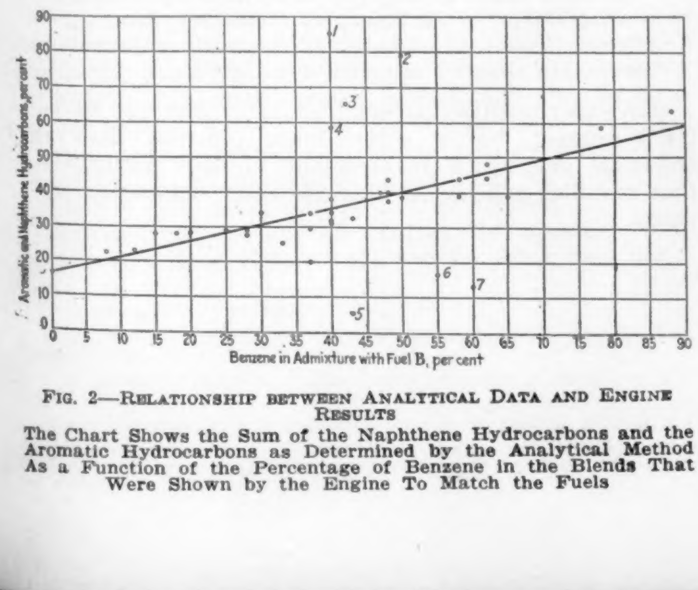

FIG. 2—RELATIONSHIP BETWEEN ANALYTICAL DATA AND ENGINE RESULTS
The Chart Shows the Sum of the Naphthene Hydrocarbons and the Aromatic Hydrocarbons as Determined by the Analytical Method As a Function of the Percentage of Benzene in the Blends That Were Shown by the Engine To Match the Fuels

was to study the combustion of hydrogen in air at high pressures, and we hoped the experiments would throw some light on the nature of the process of combustion. A series of experiments was completed 2 years ago. The apparatus was then revised and another series of experiments was made during the last year. The analysis of these experiments is not yet complete. The first set of experiments dealt with mixtures varying from one explosive limit to the other in addition to varying volumes, the initial pressure and temperature being held constant. The last set of experiments covered a range of mixtures from one explosive limit to the other with five different temperatures in each case, the initial pressure and volume being held constant. Records were obtained by using an optical indicator developed for these experiments, photographic plates recording the pressure-time curve on polar coordinates.

The correct mixture of air and hydrogen is a fast-burning mixture; there is no preliminary slow pressure-rise or combustion process preceding the fast rise in pressure. Immediately upon igniting the charge, the pressure rises very fast and maintains a high rate nearly to the maximum pressure. With leaner mixtures, say 1.0 hydrogen to 3.6 air, the combustion process starts off slowly and speeds up quickly to a very fast rate; then it slows down to a more nearly uniform rate. This speeding up and slowing down of the combustion process is most noticeable in the range of mixtures from 3.5 to 5.0 air per unit volume of hydrogen.

At the 5 to 1 air-hydrogen mixture, with certain conditions, principally smaller volumes, the combustion process appears to be the same as that experienced in the detonation of the internal-combustion-engine charge. The process starts slowly, speeding up rapidly until the pressure and the mean temperature are approximately double the values under the initial conditions, when the pressure rises practically instantaneously to the maximum pressure. A practically instantaneous rise of pressure from start to finish, with no preliminary process, can be obtained with small volumes of the correct mixture.

For the leaner mixtures which have the appearance of detonation, the maximum pressure is not as high as would be expected, making use of the best information on specific heats and dissociation, there being a considerable heat-loss from the charge to the walls during the process of combustion which readily accounts for the lower pressure. At no time when hydrogen reacts with air in these experiments and gives the appearance of detonation does the maximum pressure exceed or even reach that which might be expected from internal-combustion-engine-charge detonation.

With hydrocarbon fuels in internal-combustion engines detonation is accompanied by an abnormally high maximum-pressure, although too much credence should not be given to the maximum pressures obtained with an indicator which has a period of vibration so low that the rate of pressure-rise will set the indicator into vibration and result in a wavy record, with maximum amplitude of vibration at maximum pressure and damping itself out with a few waves of successively smaller amplitude. In all the experiments referred to, when this type of vibration appeared, an analysis of the natural period of vibration of the indicator parts or other connecting parts gave evidence as to which part of the mechanism was the offending member.

I would like to see a photographic record of the pressure-rise and fall in an internal-combustion-engine cylinder during detonation, such record to be free from the effect of inertia or period of vibration of the indicator, so that the actual behavior of the pressure during and immediately after detonation would be determined. The indicator which will give this record should have its pressure element located in the combustion-chamber wall; require a large force to obtain a very small deflection, say about 0.001 in. or less; and have its movement magnified by means of a beam, knife-edges, mirror, and point-source of light. The indicating mechanism should be a perfect elastic system, having no friction and a very high natural period of vibration. Experience with piston-type indicators has led to lack of confidence in this feature, since it has been found that there is either too much friction or leakage. Usually, considerable movement is used, say 0.01 in. or more, and an inertia effect is noticeable in dealing with rapid rates of combustion.

From what is known of energy liberation and heating of gaseous mixtures, it seems that abnormally high pressures such as are experienced in detonation in internal-combustion engines would be due to one or more or perhaps all of the following reasons:

(1) A momentary energy liberation in excess of what is anticipated

(2) A volume increase larger than the reaction equation of the fuel would indicate

(3) The formation of an unstable compound with a specific heat much lower than that of the products of combustion ordinarily formed

A correct determination of the maximum pressures during detonation and the behavior of the pressure immediately thereafter might throw some light on the nature of the reaction taking place.

W. A. GRUSE:—In his written discussion, Dr. Faragher states that we undertook the determination of proper factors for equivalents, as to detonation, of the four basic classes of hydrocarbons. He seems to have misinterpreted our paper. What we actually determined was the equivalence, by direct engine-tests, of three of the commoner members of the hydrocarbon classes in question. That we had no intention of offering our results as establishing the ultimately correct ratio is clearly brought out in our conclusion, which we quote, as follows:

> We have found a ratio for knock-reducing tendency of a naphthene, an olefin and an aromatic hydrocarbon differing from that indicated by the work of Ricardo. The subject deserves complete investigation.

Our experimentally determined ratio may not be entirely correct, but it seems more probable than an empirical one which involves the unlikely assumption that paraffins and olefins have the same detonating tendency.

DETONATION SPECIFICATIONS FOR AUTOMOTIVE FUELS

BY GRAHAM EDGAR[25]

ABSTRACT

TENDENCY to detonate is probably the most important factor in determining the usefulness of fuels for internal-combustion engines. Although it is possible, by various means, to measure more or less accurately the relative knocking-characteristics of fuels, no way has heretofore been found of rating fuels that does not depend upon some arbitrary non-reproducible conditions and measurements. The general methods adopted have consisted in comparing one fuel with another, but no absolute standard has been available.

Knocking is a function of several variables, the knocking characteristics of which have been found by keeping a certain number of them constant while certain others are varied, thus rating them in terms of load, the spark-advance necessary to produce knocking, the position of the throttle at which knocking begins, and the like. A second method consists in keeping all operating factors constant and comparing the fuels in terms of some non-knocking fuel, such as benzol, or some antiknocking fuel, such as tetraethyl lead, which must be added to the poorer of two fuels to make its knocking characteristics identical with those of the better one.

To draw detonation specifications for fuels, a reproducible primary standard fuel must be developed and methods of comparing fuels must be agreed upon. The composition of gasoline is so complex and the knocking characteristics of its different constituents are so varied that great difficulty has been encountered in finding one or more hydrocarbons, the purity of which could be definitely established by test and which would thus be absolutely reproducible.

Two hydrocarbons are cited that seem to be ideally suited for standard reference fuels, namely, pure normal heptane C_7H_{16} and pure octane C_8H_{18}, which is prepared synthetically from tertiary butyl alcohol. By mixing these two hydrocarbons in different proportions it is said to be possible to duplicate the knocking characteristics of any commercial fuel between the limits of 60 per cent of heptane and 40 per cent of octane and 40 per cent of heptane and 60 per cent of octane. These hydrocarbons are also said to be almost identical in volatility, chemical composition and other physical properties, and that, consequently, irregularities are not to be feared.

To make possible the drawing of detonation specifications for automotive fuels, it is therefore necessary only to specify that the knocking characteristics of a fuel for a given purpose should be equivalent to those of a mixture of any desired proportions of the heptane and octane in question and to agree upon one method of testing or some one of a number of methods that may be satisfactory.

The discussion following the paper centers on the chemical difference between the two standard fuels and what accounts for the difference in their knocking qualities; on a theory concerning the properties of motor fuel which indicate its tendencies to knock; and on the effects of mixtures of heptane and toluene, and octane and toluene.

THE DISCUSSION

H. A. HUEBOTTER[26]:—I note from Dr. Edgar's paper that his two standard fuels differ from each other only by one atom of carbon and two atoms of hydrogen, so far as the chemical formula goes. Physically, they are very similar except for their knocking tendencies. Will Dr. Edgar state whether there is any other difference between those two fuels, chemically, which would account for the difference in the knocking qualities? I understand that the heptane is an ordinary hydrocarbon of the paraffin series such as we would get in petroleum oil. Can the octane be derived from petroleum or is it different structurally from the ordinarily recognized paraffin series? Can that be made to account for the difference in the knocking qualities? I understand that the heptane is an ordinary hydrocarbon of the paraffin series such as we would get in petroleum oil. Can the octane be derived from petroleum or is it different structurally from the ordinarily recognized paraffin series? Can that be made to account for the difference in the knocking qualities? I have always understood that the more complicated the molecule is, the greater is the tendency to knock; but these two fuels seem to dispute that opinion.

DR. GRAHAM EDGAR:—Regarding the question as to why one of these fuels knocks and the other does not, I wish very much I knew. Answering the question as to the occurrence of these materials in petroleum, I do not know whether the particular octane we have comes from petroleum or not, but I will add this point to the chemistry of the paraffin. There are nine theoretically possible paraffin heptanes of different structures, and of course one branched-chain compound known as isoheptane. We have prepared all nine of those in our laboratory and have measured their knock-inducing characteristics as well as their antiknock characteristics. We find that no two of them are the same. The difference in the different members is about the same difference as between the two hydrocarbons I have mentioned, normal heptane and 2 to 2 to 4 trimethyl pentane.

PROF. G. G. BROWN[27]:—I offer a suggestion along that line in the form of a theory concerning the properties of motor fuel which indicate its tendencies to knock. Work that Dr. Watkins and I have done, the results of which have been published[28], indicates that there are two properties of a fuel that determine its knocking tendency. One is the rate of rise of pressure as determined in a progressive reaction in the bomb, and the other is the ignition temperature of the fuel. I believe that this particular octane has a rather high ignition-temperature. This hypothesis will also account for the fact that benzol and normal octane have about the same rate of rise of pressure; whereas, they have markedly different knocking-tendencies because benzol has much higher ignition-temperature. The hypothesis so far seems adequate to explain most of these rather puzzling discrepancies.

W. A. GRUSE[29]:—Has Dr. Edgar tried a mixture of normal heptane and toluene?

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[27] Professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

[28] See *Industrial and Engineering Chemistry*, March, 1927, p. 366.

[29] M.S.A.E.—Director of petroleum investigations and industrial research fellow, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh.

DR. EDGAR:—It is possible to substitute for the octane some such material as benzol. There is a practical objection, I think, to the use of those materials in engine testing. When you take a material like heptane with a low specific gravity and add to it the mixture of material of high specific gravity, the viscosity and the specific gravity of the fuel change. That brings up the moot question in engine testing as to whether you should use a constant air-fuel ratio for every mixture, and just what changes you should make. Therefore, I felt it preferable, instead of using benzene, to use a material in which the percentage of hydrogen and carbon does not change appreciably for different mixtures. I think this method would be superior to the mixture of heptane and toluene for that reason.

MR. GRUSE:—What is the actual difference in the performance of mixtures containing toluene and octane?

DR. EDGAR:—I have never compared mixtures of heptane and toluene in our laboratory.

A MEMBER:—In connection with Dr. Edgar's last few remarks, it seems a precautionary measure would be to use antiknock values where these structures give different antiknock characteristics and there is just one change in the atom. Where those coincidences occur, we found that they ran as many as 30 to 40 fuels. The values should be scrutinized very carefully before they are accepted as a standard.

H. K. CUMMINGS[30]:—Has a general relation been found to indicate that the isomers are in general less likely to knock than the straight-chain hydrocarbons and, if so, how does the knocking ability of hexamethyl ethane, the most compact of the octanes, compare with trimethyl pentane?

DR. EDGAR:—So far as we know, the normal straight-chain hydrocarbon is worse than any of the others; but the work on the relation between chemical structure and knocking characteristics has not progressed to the point where I can tell you anything.

ULTRA-VIOLET SPECTROSCOPY OF ENGINE-FUEL FLAMES

BY GEORGE L. CLARK[31] AND A. L. HENNE[32]

ABSTRACT

DETAILS are given of the method of control of the engine so that quantitative and reproducible measurements of detonation and comparisons with spectra can be made. Typical data are tabulated and photographs are shown of the free-burning flames of hydrogen, carbon monoxide, methane, gasoline in a blow-torch, and the like. The spectra of explosion and of detonation in the engine confirm earlier conclusions. By means of a synchronous shutter, the spectra of radiation during the four quarters of a stroke are obtained for straight-run gasoline under detonating and non-detonating conditions for the same fuel containing tetraethyl lead, aniline and iodine as knock suppressers and for cracked-gasoline blends. The outstanding result is that, during detonation, the first-quarter spectrum extends far into the ultra-violet, that of the second quarter, a somewhat less distance; the third and fourth quarters are characterized by very little radiation energy. During normal explosion, or when knock suppressers, irrespective of their chemical nature, are used in the engine under detonating conditions, the spectra of all four quarters have the same length and essentially the same intensity. Lead emission-lines from tetraethyl lead appear only in the first quarter. These and other facts are considered in the light of theories of the mechanism of knock suppressers and inducers.

In the discussion following the paper the value of spectroscopic investigation of the fluid reactions in an engine is set forth, data to show that the ionization theory is wrong are referred to, and an illustrated description of a theory of detonation is presented.

THE DISCUSSION

H. A. HUEBOTTER[33]:—The spectroscopic investigation of the fluid reactions in an engine unquestionably offers valuable data from which to study the mechanism of detonation. The outstanding contribution of the paper seems to be that the physical processes within a detonating fuel are entirely different from those attending normal combustion. The intense white flash of detonation is accompanied by invisible emissions the wavelengths of which include almost the entire middle ultra-violet range of the spectrum. The blue, red, or yellow flame of combustion produces waves that extend only half way into the near ultra-violet region. The total energy evolved by detonation is evidently liberated in a shorter time than that of combustion.

Heretofore, our efforts have been directed to limiting the rate of evolution of this energy by the use of antiknock compounds. May that not be a makeshift to render the fuel suitable for our present engines? The logical plan of engine development seems to be to harness the electromagnetic energy of detonation and convert it into mechanical work. The fact that the high-frequency waves of the middle ultra-violet region are produced during the first quarter of the expansion stroke indicates that the constant-volume reaction of the ideal Otto cycle is most nearly approached by detonation.

The spectra obtained from the knocking engine are consistent with the demonstration presented in the paper on Radiation Characteristics of the Internal-Combustion Engine[34], by Thomas Midgley, Jr., and H. H. McCarty. The authors proved that a detonating fuel caused abnormal radiation-losses to the cylinder-walls. The energy was liberated by the detonation but was absorbed by the cylinder before it could be utilized. The spectra of the detonating fuel show likewise that energy is being evolved at an extremely rapid rate by the reaction.

The banded structure of the spectra and the complexity of the fuel make the interpretation of the results rather difficult. The absence of arc lines and spark lines in the spectra of the detonating fuel preclude the probability of dissociation of the molecule or ionization of the atom. A simple fuel such as hydrogen might, however, exhibit

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[34] See THE JOURNAL, February, 1924, p. 182.

such lines in the first quarter of the stroke, and thereby offer a clue to the violence of the interatomic reactions. In any event, its spectrum should be analyzed more readily.

The tabulated data covering the conditions under which the engine was operated show that the load, the speed, and the cylinder temperature were held substantially constant. To make the test records more valuable, I request further information. What temperatures are indicated by 8.9 and 10.8 millivolts? What was the approximate ratio of fuel to air during the tests or, in the absence of specific figures, did the exhaust contain unburned fuel? We should expect some free carbon in the exhaust under detonating operation. Did the quartz window become sooted during those tests? Was the ignition fixed for the entire research, or was it adjusted for best power at all times? We recognize the fact that detonation can be induced by increasing either the cylinder-wall temperature or the compression-pressure. Were all the tests conducted with the throttle fully opened to give the maximum compression? Most of these questions arise from the fact that commercial straight-run gasoline developed less power than ethyl and cracked gasolines, and all contributing causes are of interest.

All automotive engineers must appreciate the possibilities in engine research and development that the paper unfolds. Whether we attempt to suppress detonation or to utilize it, and whether we adapt the fuel to the engine or the engine to the fuel, the photography of the electronic and the atomic movements seems to be the means by which we must learn to design and operate the internal-combustion engine.

LIEUT. WALTER C. THEE[35]:—The radiation theory for some time has seemed to me to be the most logical theory that thus far has been presented. With regard to the plus and minus charges which Dr. Clark mentions, with the nucleus of unit charges or ions in the center and negative charges or electrons on the orbit, Fig. 4 is a simple diagram to illustrate the ionization theory. When the fuel is first ignited at the spark-plug, electrons are shot off the orbit. These electrons travel at a very rapid rate and accelerate in speed as they travel. The greater

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[36] See *Industrial and Engineering Chemistry*, December, 1925, p. 1226.

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[38] M.S.A.E.—Chief of the heat and power division, Bureau of Standards, City of Washington.

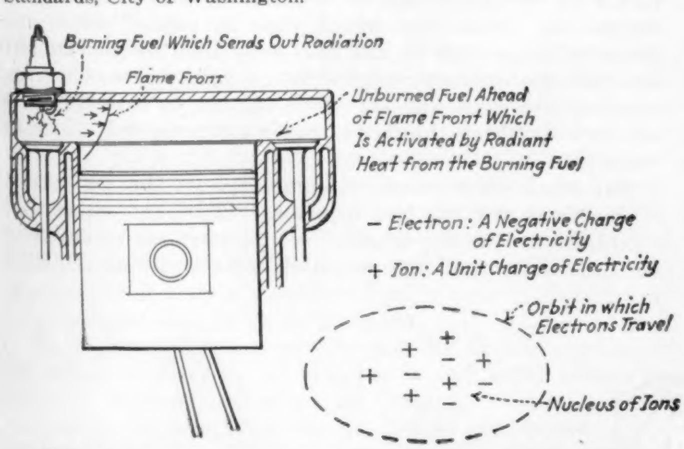

FIG. 4—DIAGRAM TO ILLUSTRATE THE IONIZATION THEORY
When the Fuel Is First Ignited at the Spark-Plug, Electrons Are Shot Off the Orbit. These Electrons Travel at a Very Rapid Rate and Accelerate in Speed as They Travel. The Greater the Distance Is That They Travel, the Higher Is the Speed Which They Will Attain, and It Is These Electrons That Are Being Emitted That Propagate the Flame. The Theory Has, However, Been Disproved

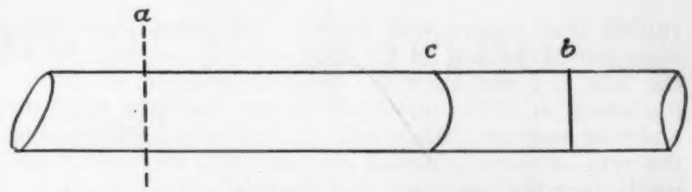

FIG. 5—DIAGRAM TO ILLUSTRATE A THEORY OF DETONATION
A Flame Is Started at *a* and Proceeds at Uniform Velocity If There Is No Change in Pressure in the Endless Tube. When the End of the Tube Is Closed at *b* and the Flame Is Allowed To Progress, Compressing Ahead of It the Unburned Charge, the Pressure and the Temperature Change; Therefore, the Constant *K* Changes and the Rate of Flame Progress Changes in a Way Which Depends Upon the Composition of the Fuel

the distance is that they travel, the higher is the speed which they will attain, and it is these electrons that are being emitted that propagate the flame. This theory really attempts to explain the manner in which flame travels, that is, flame propagation, and was disproved in a paper entitled Effect of Knock Inducers and Suppressors upon Gaseous Ionization[36], by G. L. Clark, E. W. Brugmann and Walter C. Thee. The results were checked by S. C. Lind, then with the Bureau of Mines, and also by Garner in England.

H. K. CUMMINGS[37]:—The ionization was found to accompany the explosion and to serve as one means of measuring the intensity.

LIEUTENANT THEE:—We have no satisfactory experimental proof thus far that the ionization theory is correct. In regard to the rate of flame propagation, if the rate is normal no knock will result and the spectrum will be confined to the visible region. If the rate is abnormal, the spectrum will extend into the ultra-violet region and be continuous; the spectrum would be expected to be confined to the infra-red region. The latter expectation has not yet been proved experimentally. I would like to see some data on spectra in the infra-red region. Dr. Clark could not photograph infra-red spectra on his machine because it was limited to the ultra-violet region.

DETONATION THEORY

DR. H. C. DICKINSON[38]:—I have been very much interested in this discussion and it has brought to mind the thought that it may be worthwhile for us to try to avoid getting too far away from some of the comparatively simple fundamental mechanical-conceptions that are a necessary part of the problem. Therefore, I wish to bring to your minds some points which I believe Thomas Midgley, Jr., brought out several years ago, points which we should bear in mind in connection with any attempt at a detailed analysis of the detonation problem such as that to which we have been listening. Undoubtedly, the question of radiation enters into the problem in a very intimate way; just how intimately we may not know, but perhaps we can find out.

Concerning the necessary mechanics, the simple straightforward mechanics of the problems presented, Fig. 5 represents an endless tube. We start a flame at *a* and we know from recent experiments that this flame will proceed at a strictly uniform velocity if there is no change in pressure. In other words, if we are working at constant pressure, and this can be done very readily, that velocity can be expressed by $K \times C_1 \times C_2$. Symbols C_1 and C_2 are the concentrations of the combining constituents, and K is a constant for any given pressure and temperature. Now K changes with pressure and temperature and just how it changes we cannot say, nor why. This is perhaps tied up with radiation. At any rate, it changes differently for different fuels. For some fuels K increases with pressure and temperature more

rapidly than it does with others. Therefore, if we have some particular fuel in the tube and we close the end of the tube at *b* and allow the flame to progress, compressing ahead of it the unburned charge, then the pressure and temperature change and, therefore, *K* changes and the rate of flame progress changes in a way which depends upon the composition of the fuel.

It is evident what must happen as that process goes on. Suppose *K* increases fairly rapidly. So long as the velocity of the flame is comparatively slow, compared to the velocity of sound, the unburned charge simply compresses slowly and the pressure is nearly uniform throughout the entire space. The pressure of the gas at the flame front is increasing gradually but not very fast, and the flame velocity also is increasing gradually. But suppose the velocity increases still more and approaches the velocity of sound. On approaching the velocity of sound, a different condition exists. When the velocity approaches fairly close to sound velocity, instead of having the entire gas ahead of the flame compressed uniformly, we have a building-up of compression at the front of the flame, and that still further and still more rapidly increases *K* and increases the velocity until a condition is very soon reached in which the velocity of the flame is equal to the velocity of sound. If this occurs at the position *c*, for instance, the entire energy which is developed in this flame front is concentrated in a very narrow space at *c* which is a fraction of a millimeter in depth, and is traveling at the velocity of sound. This means that the pressure at point *c* goes up to possibly 100 atmospheres and of course the temperature goes up correspondingly and we have a condition which is fully capable of preigniting almost anything.

At this stage there is a bit more to the problem. The velocity of sound in the burned mixture between *a* and *c* is considerably higher, about twice as high as in the unburned mixture, and still energy can escape backward; so, some energy is still getting away from the wave-front, but the velocity is high enough at the point *c* and the pressure is high enough to ignite the charge spontaneously and the velocity increases to that of the velocity of sound in the burned mixture, and then from there on the explosion or combustion wave proceeds as a compression wave at a velocity equal to the velocity of sound in the burned portion of the charge and with a pressure possibly equal to that of several hundred atmospheres. The entire performance takes place in the layer of a few tenths of a millimeter thick, but moving like a sound-wave or a wave on water.

Does the measurement of radiation tend to explain what happens or is what happens mechanically the cause of the phenomena of radiation? There are some things which make it look as if the fundamental mechanical cause is after all the important thing, possibly involved with a molecular or atomic structure of the fuel and perhaps the radiation will enable us to find out more about the nature of these phenomena than it will about the reason that the velocity increases.

R. E. WILSON[39]:—I have not been able to decide whether I have been stubborn or farseeing in that my theory of detonation has not been changed in the last 4 years. I believe that some sort of activating radiation is sent ahead by the flame-front which is absorbed by the anti-knock materials, but I do not consider that it has been proved one way or the other as yet. That is the simplest explanation of the essential facts which I have been able to formulate. Different fuels are different in the amount or kind of activating radiation. The various antiknock agents differ in the extent to which they absorb those radiations. I think this accounts for most of the known facts, not including some of the wild statements that have occasionally been made regarding the phenomena.

PROF. G. G. BROWN[40]:—There is one point I would like to bring out, since Dr. Dickinson has stated the phenomena of engine detonation as being practically identical to the detonation wave investigated by Dixon in England. If the initial temperature of the explosive gases in a bomb such as has been described by Dr. Dickinson is increased, the tendency to set up the detonation wave is greatly reduced and in many cases absolutely eliminated. This fact has been proved by every investigator that has ever worked with gaseous explosions in bombs, and reported the work in the literature.

In an engine it is known that an increase in temperature will make the knock worse. In a progressive reaction as described by Dr. Dickinson, an increase in the initial temperature will decrease or eliminate the detonation wave. Therefore, there is some important difference between the mechanism of the detonation wave as described by Dr. Dickinson and that as occurring in the engine.

There is no question but that every fact brought out by Dr. Dickinson is absolutely true, but he has overlooked this fact concerning the effect of temperature. In an engine, something seems to happen ahead of the flame, due to radiation, adiabatic compression, or something else. The mechanism described by Dr. Dickinson does not, in my opinion, cause engine knock because, if it did, an increase in temperature would eliminate the knock. This is contrary to fact except in very rare cases where a so-called "cold knock" is noticed on an indicator in an engine. Sometimes when an engine is cold a detonation knock is noticed which is eliminated when the engine warms up. This cold knock may be caused by a progressive flame such as has been described by Dr. Dickinson, but the ordinary engine-knock gets worse when the temperature rises and therefore cannot be a progressive reaction in which the flame moves progressively through the mixture.

Our work on detonation, conducted at the University of Michigan for the last 6 years, will be summarized in a bulletin of the department of engineering research of the University that is to be published about May 20, 1927.

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Recent Development in Aircraft Powerplants

By LIEUT. C. C. CHAMPION, JR.,[1] U. S. N.

BUFFALO SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWING

ABSTRACT

NAVAL aviation confined its activities to training and to coastal patrol during the World War. This limited operation was necessitated by the small amount of material suitable for operation over water, the strategical and geographical situation which determined the nature of the naval operations, the very limited performance of seaplanes of that period, and the fact that warships were not equipped for handling aircraft or prepared for aircraft cooperation. At the end of the War, naval aviation was made part and parcel of the fleet.

Fighting airplanes are required to gain and maintain control of the air. Observation airplanes are used for short-range scouting and also for controlling long-range fire of capital ships by reporting the fall of shot to the ship by radio. For torpedo and bombing work, the first requirement is large weight-carrying capacity. A definite need exists for scouting and patrol operations at great distances from the fleet or base, requiring flights of great range and duration. In the present state of development, the multiple-engine flying-boat seems best suited for this purpose. Training airplanes need have only limited performance and require some skill on the part of the pilot. They should have low first and maintenance costs but weight, within reasonable limits, is not considered as being especially important.

The two accepted arrangements of aircraft engines for naval use at present are the radial and the in-line, and the cooling is by air or by water. An analysis of troubles experienced with water-cooled engines shows that a large proportion are due to failures of some part of the water system. The weight per horsepower, dry, of the most modern types of engine, is approximately the same, but it is a misleading comparison in that the chief concern is the weight of the powerplant when ready to fly. Air-cooling eliminates the troubles and the additional weight due to water-cooling. In the matter of mechanical dependability, there seems to be little choice between the engines proper of the two types. From the viewpoint of fuel economy, the two types are equally good.

Three distinct types of engine are now being produced for the Navy. Two models, practically identical in design and construction, are Packard engines of from 500 to 600 hp., and of 770 hp. respectively. Each is a 12-cylinder 60-deg-V type. The Wright nine-cylinder Model J-5 radial air-cooled engine and the Pratt & Whitney engines are the other two types.

After detailing various phases of flight experience, the author discusses superchargers, starters, ignition, the fire hazard of airplanes, gearing of airplane engines, heavy-oil solid-injection compression-ignition engines for aircraft use, and steam powerplants for the same purpose. He said that the solid-injection engine lends itself most favorably to the propulsion of rigid airships and that the steam powerplant is not worthy of serious consideration for aviation purposes in any form which has been devised to date.

Steady progress in engine design and engine building has resulted in a line of excellent powerplants produced to meet naval needs; one engine to date has found much favor with commercial users; and a line of engines has been developed that should fill commercial as well as naval needs.

The discussion cites some further features of engine lubrication, including a brief description of a centrifuge and its action.

NAVAL aviation confined its activities to training and coastal patrol during the World War. This limited operation was necessitated by the small amount of material suitable for operation over water, the strategical and geographical situation which determined the nature of the naval operations, the very limited performance of seaplanes of that period, and the fact than men-of-war were not equipped for handling airplanes or prepared for aircraft cooperation. By the end of the War, the great naval value of aircraft had made itself apparent. The problem was subjected to very complete analysis and, in spite of the amazing difficulties which maritime operation of aircraft presented, it was apparent that the only sound solution was to make naval aviation part and parcel of the fleet.

For several years after the signing of the Armistice the public showed little interest in anything having to do with National defense and Congress did not see fit to provide for anything but the barest necessities of the various Services. At that time, there were huge war-stocks of aviation materiel on hand, which was fortunate in one sense because it provided the equipment for some training and for limited operations. It was unfortunate because the materiel was not entirely suited to the needs of the Services, was obsolescent, and the stock was so enormous that it became a drug on the market and thus delayed the start of new development. The Liberty-12 aircraft-engine is the most notable example of this.

The lines along which materiel is to be developed must be in conformity with the service which the materiel will be called upon to render. A statement of the general aircraft-problem of the fleet will assist in clarifying the needs for the types of airplane and engine in use. It is axiomatic that for the maximum of effectiveness the fleet must strike its maximum blow at the enemy's most vulnerable point. This requires perfect coordination of effort of a multiplicity of types of surface, sub-surface, and aircraft. In this effort aircraft must play many roles, both before and during an engagement. Six different functions must be fulfilled and thus, with the addition of primary training, there are seven types of service for which material must be provided.

SEVEN TYPES OF SERVICE

Fighting airplanes are required to gain and maintain control of the air. On the offensive, they take the air for

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the purpose of destroying enemy aircraft of all types, including the enemy's fighting airplanes. When opportunity offers, they may also harass surface vessels by machine-gun fire directed at unarmored positions, such as the fighting tops from which the ship's battery is normally controlled and the positions where the crews of anti-aircraft guns operate. On the defensive they protect our own aircraft of other types while carrying out their mission, and if necessary protect the surface vessels from attack by enemy fighting-airplanes. Thus they must carry out an offensive action in accomplishing a defensive mission.

The fighting airplane has one or more machine guns fixed to fire straight ahead and synchronized to fire between the blades of the propeller. To carry out their mission, they must be able to take the air on an instant's notice and have the highest speed practicable with the maximum climb and maneuverability. Climb and maneuverability are particularly important. Climb is necessary to get on station in the least possible time and, in combat, to attain the very valuable altitude advantage. Maneuverability is important because the fighting airplane must aim its guns by pointing the entire airplane directly at the target. Maneuverability is equally important for defense, as the airplane's speed and maneuverability are the only defensive measures at the command of the pilot.

Observation airplanes are used for short-range scouting and also for controlling long-range fire of capital ships by reporting the fall of shot to the ship by radio. For both of these purposes, some protection is needed so that these airplanes carry both fixed guns and flexibly mounted machine-guns which are used for protecting the airplane from attacks from above or behind. These airplanes must be somewhat larger than fighting airplanes as their duty requires at least two men, one for piloting and the other for observation and radio operation. They must have the highest practicable speed to operate through a reasonably large range in the least possible time. They must also have good climbing characteristics to get on station promptly, and good maneuverable qualities for their own protection when attacked. As these airplanes are carried on battleships and cruisers, their size and weight must be kept at the minimum.

For torpedo and bombing work, the first requirement is large weight-carrying ability. This dictates the use of an airplane of considerable size which, in practice, is found to be about the maximum size that can be handled conveniently aboard ship. Torpedo and bombing operations are not carried out at great distances from the fleet; therefore, the amount of fuel necessary for these functions is limited. By adding more fuel to the useful load at the expense of the torpedo or bomb load, the cruising range of these airplanes can be increased materially so that the airplanes lend themselves reasonably well to medium-range scouting-operations. The Navy has developed a three-purpose airplane to carry out the combined functions of torpedoing, bombing, and scouting. Naturally, the finished product is a compromise between the three ideal types, so that it cannot be expected to be ideally suitable for any one of the three purposes.

A definite need exists for scouting and patrol operations at great distances from the fleet or base, that is, for flights of great range and duration. In the present state of development, the multiple-engine flying-boat seems best suited for this purpose. The nature of the long-distance patrol requires exceptional seaworthiness and a large crew to provide relief pilots, radio-men, and mechanics. The large flying-boat can carry sufficient fuel for great range and duration of flight and is the most seaworthy type. As these airplanes must operate without the protection of escorting fighting airplanes, they must carry their own protection. This is accomplished by utilizing the comparatively large crew for manning numerous flexibly mounted machine-guns, placed so as to cover practically all sectors. A well-protected flying-boat has become a very formidable target.

Primary training cannot be considered a strictly military function. It is conducted at points remote from the theater of war, and its mission is to train the maximum number of pilots with the minimum number of accidents and the least cost. It becomes, therefore, almost a commercial enterprise. Training airplanes need have but a very limited performance and require considerable skill of the pilot. The first cost and maintenance costs must be low, and reliability becomes a most important factor in avoiding accidents. Weight, within reasonable limits, is not important.

Functions of Fleet Units

Each unit of a fleet has two functions. First, it is a vehicle to carry its armament into position for battle and, second, it is a platform from which its offensive power is directed at the enemy. Each type is a compromise between mobility, offensive power and defensive strength. Speed and range are reciprocal factors, and also, in practice, speed and structural strength. Aircraft, therefore, being by far the fastest units, have the least cruising range, except the patrol type in which almost the entire useful load is allocated to fuel, and are inherently the most fragile. On long cruises, the smaller vessels and the fastest types must be refuelled at sea. Aircraft must literally be carried into battle, and out of it, on the backs of the fleet. Modern warfare recognizes the 24-hr. day and the 7-day week in war as well as in peace and, in spite of their fragility, naval aircraft must be capable of functioning in fair weather and foul.

The difficulties of providing for operation on short notice irrespective of the state of the sea, as well as the limitations of aircraft imposed by shipboard operation, have exerted a profound influence on the development of material. The problem divides naturally into three parts; (*a*) handling aboard ship, (*b*) the take-off, and (*c*) landing and hoisting-in. On the aircraft carriers these problems are difficult enough. Large stowage spaces, elevators, and an unobstructed flying-deck are provided. Lightly loaded and high-performance airplanes are flown off the forward part of the ship in the same manner as they are flown off a landing-field. Heavily loaded airplanes are assisted in accelerating to flying speed by special gear carried by the ships. Landings are effected on the after part of the flying deck, where special arresting gear is installed.

On ships which carry aircraft as auxiliary equipment, these problems are entirely different and vastly more complicated. These ships have no deck space of sufficient area for landing or for taking-off; in fact, they require so much space for turrets, masts, bridge, funnels, and other top hamper that even the stowage of one or two small airplanes on deck requires careful consideration. An airplane on a flying-field ½ mile square looks like a very small object. The same airplane aboard ship assumes enormous proportions. As landing aboard is out of the question, seaplanes must be used.

The problem of the take-off has been solved by the catapult, which, incidentally, usually takes care of stowage aboard. After flight the seaplane must land on the water and be hoisted aboard. Thus, storage and hand-

ling facilities definitely limit the size of naval aircraft, while hoisting and arresting limit the permissible weight. Also, the maximum permissible landing-speed, the stalling speed, is definitely fixed by the limited speeds which can be provided for getting the seaplane into the air, as well as the stresses imposed on the structure of the seaplane by the arresting gear and landing in rough water.

Lift-Drag Ratio

Besides the limitations placed on the size and weight of naval aircraft another limitation, the lift-drag ratio of the airfoils, must be reckoned with constantly. In any given airplane this ratio determines how much lift is available for useful load after the weight of the complete airplane has been provided for. Thus, in choosing a powerplant, the two most important values are the pounds per horsepower and the horsepower times the specific fuel-consumption. Every pound which can be saved in the powerplant permits not 1 but 3 lb. to be added to the useful load, because 1 lb. can be taken from the structure necessary to carry the pound saved and another pound comes out of the wing structure necessary to support the 2 lb. so saved. This saving in weight and size will then reduce the power required to propel the airplane, which result is directly convertible into increased performance, greater range or a still further reduction in weight due to the reduction in fuel carried, tankage, and the like. Any decrease in the specific fuel-consumption effects a similar improvement in the entire airplane. This is of greatest value in long-range aircraft, in view of the fact that modern engines burn their weight in fuel in 3 to 5 hr. It is generally accepted that, due to the savings in weight, size and fuel consumption made possible by the use of aircooled engines, any given job can be done with 75 per cent of the power that would be required with a water-cooled powerplant.

Dependability and Maintenance

Dependability in an aircraft powerplant is of utmost importance. It is so closely inter-related to durability that these two properties can be considered together. A failure of the powerplant results in an immediate landing which frequently forces the pilot to bring the airplane to earth under very adverse circumstances. This failure then hazards not only the powerplant but the personnel and the entire airplane.

Much has been accomplished in recent years to increase the dependability of aircraft powerplants. Improvements in design have resulted in a general increase in simplicity and ruggedness. Improvements in manufacturing methods, in heat-treatment and in the materials used, have resulted in greater strength and uniformity in the component parts. These improvements have been featured in the paper entitled Progress in Aircraft-Engine Design[2], by Arthur Nutt, and in the paper on Air-Cooled Engines in Naval Aircraft[3], by Commander E. E. Wilson, U. S. N.

Of equal importance are the improvements in operation. Increased knowledge on the part of the operating personnel resulting from intensive application and instruction have eliminated many faults. This has been carried to the last logical point through the use of the check-off list. When new material is put into service, it is given the most severe treatment possible on the test stand and in actual flight. The results of these tests are used, first, to eliminate the faults of design and the weaknesses of the material; second, to provide check-off lists for the operating personnel. Upkeep and operation of modern military-aircraft are complicated processes, and it has been found that check-off lists are necessary if no omissions are to be permitted.

Ease of maintenance has been a logical sequence to improvements in design and manufacture. The personnel available for operating naval aircraft is limited in training and in numbers. The operating demands are such that ease of maintenance is a most important consideration. This increase in the ease of maintenance becomes apparent in the comparison between the Liberty-12 engine on the one hand and a modern radial-air-cooled-engine on the other. For strictly military purposes, the cost of material cannot be given the same weight that must be accorded it in commercial operation. Cost, however, is very important because it is a direct limitation on the amount of material which can be procured with the funds available. The ultimate cost of aircraft powerplants, however, has been materially reduced through improvements in design, in material, and in operation, which have resulted in greatly increased operating life and lowered costs of maintenance. Simplicity in design and improved methods of manufacture have also taken care of another serious problem, that of the immediate expansion of production, or supply, in the event of hostilities.

Comparison of Types

In determining the general characteristics of aircraft engines for naval use, a comparison of types is very interesting. Two fundamental differences are (*a*) the arrangement of the engine and (*b*) the method of cooling. At present there are but two accepted arrangements, the radial and the in-line types and, of course, air-cooled and water-cooled. An analysis of troubles experienced with water-cooled-engine installations shows at once that a large proportion of the failures which have occurred are failures of some part of the water system. Besides being the source of frequent failures, the water system adds ½ lb. or more per hp. to the installed weight of the powerplant.

Comparing the most modern types of engine, we find that the weight per horsepower dry is approximately the same. This, however, is misleading and is a valueless comparison as we are concerned solely with the weight of the powerplant ready to fly. Air-cooling eliminates both the troubles and the additional weight attendant upon the water cooling-system. In the matter of mechanical dependability, there seems to be little choice in the engines themselves. The elimination of the water system results in a net gain of 25 to 40 per cent. From the viewpoint of fuel economy, the two types are equally good.

In the older air-cooled engines, the fuel consumption was definitely inferior to that of the water-cooled engines. Recent changes in cylinder design, which provide for better cooling of the head and a better form for the combustion-chamber, have brought the fuel consumption of the air-cooled engine down to that of the best water-cooled types. The air-cooled engine seems definitely superior to the water-cooled engine viewed from the point of ease of maintenance by completely eliminating radiators, water piping, water-pump, jackets, and a large number and variety of hose connections and glands. In the matters of cost and production, there seems to be little or no choice, but in the latest types it is indicated that the air-cooled engine is outstripping its competitor in these desirable features.

Water-cooling does not lend itself readily to radial

[2] See The Journal, September, 1926, p. 239.
[3] See The Journal, September, 1926, p. 221.

construction and in this Country water-cooled engines in general use are all of the V-type. In the air-cooled engines, the radial is the only arrangement which seems to provide uniform cooling. I do not mean to infer by this that the V-type air-cooled engine cannot be properly cooled. An air-cooled Liberty-12 engine has been put through extensive flight-tests and I believe that satisfactory cooling has been obtained. This engine is fitted with an air-scoop which forces the air into the V and out at the sides between the cylinders. The radial type, however, provides for direct air-flow to all cylinders without any change in direction of the normal air-flow, and makes possible the ideal cylinder-head, with the head, the valve-seats, and the valve-guides exposed to the maximum air-flow.

The in-line engine requires a camshaft enclosure along each bank. The radial type, by having the cylinder-heads arranged in a circle, utilizes the maximum amount of air available from the propeller, while the V-type engine gets the air from a 60-deg. sector. It is believed this will be an important feature for ground-test running, for warming-up, and the like, especially in warm climates. The radial engine has the distinct advantages of the short rigid single-throw crankshaft, which eliminates the torsional vibration troubles incident to the longer crankshaft required for the V-type engine. The compactness of the radial engine is very advantageous from the point of view of the airplane designer, as it permits a shorter fuselage and a more concentrated disposition of the principal loads. This is very important from the viewpoint of the weight of structure required and for

[4] See THE JOURNAL, December, 1926, p. 609.

[5] See THE JOURNAL, September, 1926, p. 303.

[6] See THE JOURNAL, March, 1925, p. 297.

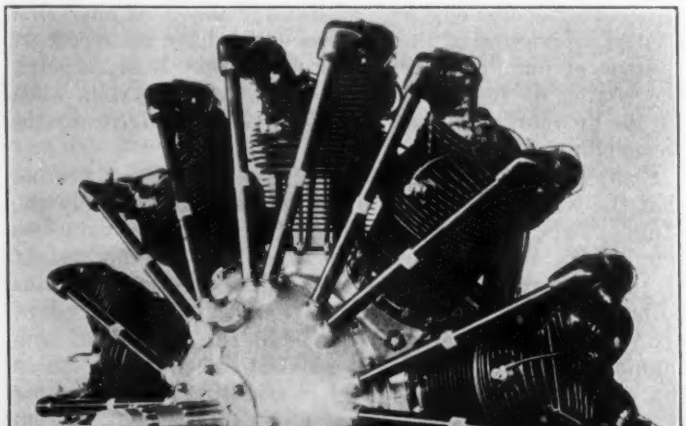


FIG. 1—PRATT & WHITNEY RADIAL AIR-COOLED WASP ENGINE
The Hemispherical Crankcase Nose Section, Enclosed Valve-Operating Mechanism and Splined End of the Crankshaft for Mounting the Propeller Hub Are Illustrated

increased maneuverability which results from the concentration of load.

The single-throw crankshaft greatly simplifies the crankcase and bearing problems. The crankshaft is carried on three bearings, a deep-grove ball-bearing at the extreme front end of the engine which takes both radial and thrust loads, and two large-diameter roller or ball-bearings immediately adjacent to the crank cheeks, which take the radial load only. The disposition of the cylinders in the form of a star greatly simplifies the distribution problem, especially when a centrifugal blower is employed to provide rotary induction.

It can be said without fear of contradiction that the distribution in the Pratt & Whitney Wasp engine shown in Fig. 1 is the best which has been seen on any service engine. An excellent description is contained in the paper on the Wasp and Hornet Radial Air-Cooled Aeronautic Engines[4], by George J. Mead. The Wright J-type engine has no rotary induction, but by employing three separate induction systems and thus utilizing the ramming effect, it obtains excellent distribution. This engine is fully described in the paper on the Development of the Wright Whirlwind Type J-5 Aircraft Engine[5], by E. T. Jones.

The ease of maintenance and servicing of the radial air-cooled engine is remarkable. Simplicity and accessibility make it possible to remove practically any part of the engine without disturbing other main parts. It is unnecessary to remove any of these engines from the airplanes except for major overhaul involving removal of the crankshaft or connecting-rods. The simplicity and ruggedness of these parts provide unusually long life between necessary overhauls. The Wasp engine is constructed so that any or all parts of the engine, except the rear crankcase-section, which provides the mounting attachments, can be removed without removing the entire engine. The principal advantage to be gained from this feature is the fact that an engine can be overhauled piecemeal; that is, one or more cylinders can be removed at a time whenever opportunity permits, until the entire engine, except the crankshaft and connecting-rod group, has been overhauled.

THE PACKARD ENGINES

At present, three distinct types of engine are being produced for the Navy. The Packard Motor Car Co. is building two models of engines practically identical in design and construction. The Model 3A-2500 Direct Aircraft Engine is shown in Fig. 2. The two models are furnished either with direct-drive or geared, and the smaller is also furnished as an inverted engine. The engines are described in detail in the paper on Recent Developments in Aircraft Engines[6], by L. M. Woolson. These engines are practically alike except for a difference in size. The smaller engine has a $5\frac{3}{8}$-in. bore and a $5\frac{1}{2}$-in. stroke, and is rated at 500 to 600 hp., depending upon the crank speed and the compression used. The larger engine has a bore and stroke each 1 in. greater than the smaller engine, that is, $6\frac{3}{8}$ and $6\frac{1}{2}$ in. respectively, and is rated at 770 hp. at 2000 r.p.m. These engines are of the conventional 12-cylinder, 60-deg. V-type. The cylinder construction is a composite design. It combines to a large degree the advantages of both the unit-type and the block-type construction, as the individual cylinder-units are readily replaced and the engines retain the general rigidity and cleanness of the block construction. The assembled cylinder-block unit and its valve-gear mounts on the engine in the same manner as on the cast-in-block unit. The crankcase is of the usual box type.

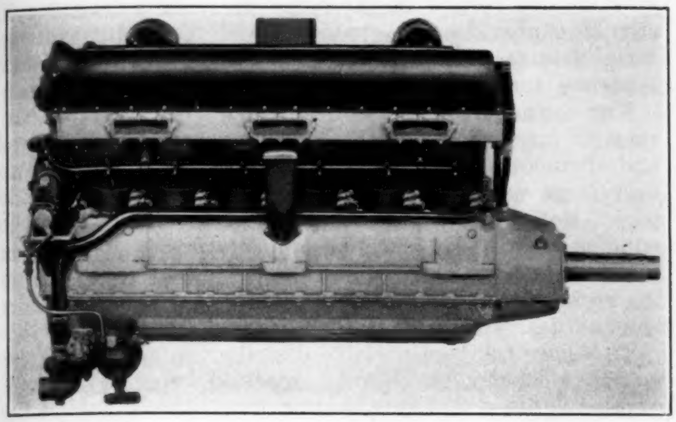


FIG. 2—PACKARD MODEL 3A-2500 AIRCRAFT ENGINE
The Engine Has a 6⅜-In. Bore, a 6½-In. Stroke, a Displacement of 2540 Cu. In. and Is Designed for Direct Drive. It Is Rated at 800 B. Hp. at 2000 R. P. M.

The main bearings are carried in transverse webs in the upper half. The forged duralumin bearing-caps are supported by large bolts running through the crankcase parallel to the cylinder axes. This V-bolt construction provides added rigidity to the entire engine. Articulated connecting-rods are used with the connecting-rod bearing babbitted directly to the steel. Slipper-type pistons are fitted in both engines. Cylinders are all-steel construction, the built-up head being welded-on as is the water-jacket. The upper end of the cylinder is secured to the valve housing by studs. The inner surface of the lower plate of the cylinder-head forms the valve-seats.

Circulating water is supplied to each cylinder at the bottom of the jacket. The water is discharged through the valve housing after passing through the double-plate cylinder-head, the water passages being disposed so as to favor the hottest parts of the head. Two spark-plugs are fitted in the sides of each cylinder. The valve housing is an aluminum-alloy casting and is adaptable to either bank. Four valves per cylinder are used. Siamesed ports are used so that the valves are paired across the cylinder-head. This arrangement permits the use of a single camshaft with a cam follower arranged to operate a pair of valves. Exhaust-valves are oil-cooled. The cam follower guide forms an oil-pump. As the cam depresses the follower, the guide, acting as a piston, forces oil through the follower and into the ends of the valve-stems. This oil is pumped down a central tube to the valve head and returns outside of the tube. It is discharged into the valve-box through ports in the valve-stem above the valve-guide. Two double carbureters are fitted in the V, each venturi supplying the three cylinders of one bank adjacent to it. Two Scintilla magnetos are fitted under the camshaft drive-shafts at the anti-propeller end, each magneto firing one spark-plug in each cylinder. Battery-generator ignition can be provided in place of the magnetos if desired.

THE WRIGHT MODEL J-5 ENGINE

The Wright Model J-5 engine shown in Fig. 3 is the latest of the series of 200-hp. air-cooled engines to be developed for the Navy. This development began in 1916 when Charles L. Lawrance started experimenting with air-cooled engines. His first efforts were with a two-cylinder opposed-piston Model-A engine which developed 28 hp. at 1400 r.p.m. The engine next appeared in the form of the three-cylinder radial Model L, which developed 60 hp. at 1800 r.p.m. Some of these engines were put into service by the Army and the Navy. The Model R-1 engine followed and, in July, 1921, it passed a satisfactory 50-hr. test. This was a nine-cylinder, 4¼ x 5¼-in. engine with a total displacement of 670 cu. in. and developing 147 hp. at 1600 r.p.m. on an average fuel-consumption of 0.52 lb. per hp-hr., an oil consumption of 0.12 lb. per hp-hr. and a weight of approximately 410 lb. This engine represented a real accomplishment. The first "J" engine, known as the Model J-1, was contracted for early in 1920. It was similar to the Model R-1 except that the bore and the stroke were increased to be 4½ and 5½ in. respectively. These dimensions have not been changed since. The first engine was delivered in May, 1921. After some delay, the 50-hr. test was made, the maximum power developed being 233 hp. The engine showed so much promise that an order for 50 of these engines was placed before the 50-hr. test was completed.

I was on duty with the squadron which was the first operating unit equipped with these engines. The first engines were not entirely satisfactory and. in the course of their operation, furnished many interesting problems. As they were radically different from anything with which naval personnel was familiar, they were looked upon with grave suspicion until they had been in service for some time. In spite of the fact that there was much to be desired in these early engines, they soon gained favor with the pilots and with the engineering department of the squadron. It is noteworthy that, after the first 6 months, during which much was learned about their operation and care, a squadron of 12 airplanes experienced no forced landing in more than a year of operation which totaled about 3000 hr. of flying.

Experience gained in the operation of these engines resulted in modifications which led to the production of Model J-3 and, immediately thereafter, of Model J-4. The principal change was one of cylinder construction. Models J-1 and J-3 employed an aluminum cylinder with fins cast integrally with the head and the barrel, and a steel liner. Later models employed a steel cylinder with cast-aluminum head screwed and shrunk on to the steel

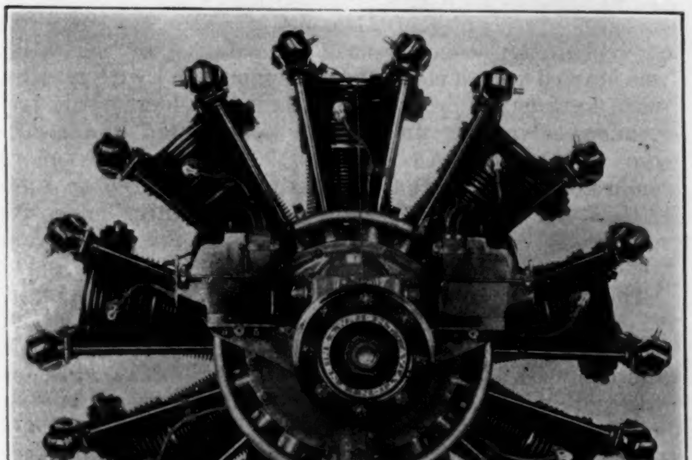


FIG. 3—WRIGHT MODEL J-5 ENGINE
Aside from the Changes Necessary To Permit Mounting the New J-5 Cylinder, the Construction of the Crankcase Was Not Altered from That of the J-4A Type

barrel. A change was also made to provide one carbureter in place of three carbureters, owing to the difficulty of keeping three carbureters properly synchronized. The new cylinder was not entirely satisfactory due to hot-spots that developed in the head. This was promptly corrected by changing the design to provide more fin area in Model J-4B. The single carbureter was not a distinct success as it eliminated, to a large extent, the ramming effect. Model J-5 is noteworthy for its entirely new cylinder, its enclosed valve-gear, and a single-unit three-barrel carbureter which furnishes the desirable effect of the three carbureters used on Model J-1 and eliminates the mechanical defects. Model J-5 is built in three sections. The front or nose section is carried in a cone-shaped aluminum-casting which forms the front of the crankcase. It carries the thrust bearing and the magneto and cam-drives at the forward end, and provides brackets on the outside for mounting the two Scintilla magnetos.

The main section of the crankcase carries the two main-bearings, houses the cam mechanism, and provides mounting pads for the nine cylinders. It also contains, in the rear, the induction passages. The rear action is, in reality, an accessory unit containing the oil-pumps and strainers, starter drive and mounting flange, gun-synchronizer drives, tachometer drive, and the fuel-pump drive and mounting flange. The valve mechanism is completely enclosed, with the rocker-arms and valve-springs housed in a streamlined box to reduce air resistance as well as to provide protection for the valve mechanism.

Pratt & Whitney Wasp Engine

The Pratt & Whitney Wasp engine is the latest development in American aircraft engines to be put into production. The first experimental engines have been given a great amount of very hard flight-service to date, as well as an unusual amount of test-stand running. The results have been uniformly excellent and the Navy considers itself fortunate to have been able to foster such a successful development. The Wasp engine represents the first effort of a new company but a company which, through its officers, might be considered to have had much air-cooled-engine experience. The design of the Wasp was started with a clean sheet of paper, and with no jigs, tools, fixtures, or previous models to consider. This tremendous advantage undoubtedly contributed to the success of the finished product. It also makes more remarkable the fact that the design was started on Aug. 1, 1925, and that the first engine was running under its own power on Dec. 24, 1925, less than 5 months from the commencement of the design.

The Wasp engine is characterized by its light weight per horsepower, clean design, simplicity of construction, remarkable ease of maintenance, and excellent operating-qualities. On an extremely conservative rating, this engine develops more power than the Liberty-12 engine on its maximum rating. The installed weight of the Wasp is approximately one-half that of the Liberty-12 engine. The magneto couplings are the only exposed moving parts on the Wasp engine, and the symmetry and form of the engine make the cowling arrangement simple, efficient and generally pleasing. All accessories are grouped in the rear section so that they are enclosed in the first cowled-in bay of the fuselage, where they are protected and also are convenient of access as shown in Fig. 4. The front cover carries the thrust bearing, cam drums and cam-drive. The crankcase is drum-shaped, and built up of two forged halves held together by nine through bolts and the cylinder holding-down flanges. The two sections are forged in the same die. This forged construction provides the strongest and most uniform material obtainable, and it also permits the use of solid-web supports for both main-bearings.

The cylinder construction employs a forged-steel barrel with integral fins, with a cast-aluminum head screwed and shrunk-on. The head is hemispherical, having two very large valves set at a large angle to the axis of the bore. Both valve-ports open to the rear which, with the wide valve-spacing, permits ample air-flow for cooling the head and the valve-seats. Large fins are provided on the rocker-boxes for cooling the valves through unusually long guides.

To secure the best possible distribution and high volumetric efficiency, a General Electric centrifugal compressor is fitted in a thin section immediately behind the crankcase. It is for rotary distribution only and is not a supercharger. Its slight supercharging effect is just sufficient to overcome manifold depression at full throttle. The impeller is spur-gear driven from the rear end of the crankshaft at five times engine-speed. It draws carbureted air directly from a Stromberg carbureter and delivers it, through a diffuser and the individual intake-pipes, to the valves.

The rear cover contains the entire accessory group. The accessories are admirably laid out in a manner which provides compactness and accessibility. The accessory group can be passed through the mounting circle of the engine, which greatly facilitates the removal of the engine from the airplane. The blower section which carries the mounting lugs and the rear cover can be left in place and a new power-unit can be bolted-on without disconnecting any parts. The oil-pump strainers are built into the casting while the magnetos, the carbureter, the starter, the fuel-pump, and the generator, if a generator is used, are mounted on flanges.

Until the advent of the Wasp engine, it had been general practice for radial engines to use a solid crankshaft and a split big-end master-rod. The master-rod big-end had been the limiting factor in crank speeds, due to flexing of the arch which resulted in cracking the web at the split, in breaking the bolts or in splitting the bolt bosses. Increasing the strength of the rod by adding metal meant adding more metal to the counterweights and transferring the failure to the shaft or to the crankcase. The master-rod used in the Wasp engine is of the solid-end type, fitted to a two-piece crankshaft. This construction also provides much better support for the crankpin bearing than is possible with a split rod, and the bearing takes the simple form of two shells pressed into the rod from either end. It was believed in some quarters 2 years ago that 1800 r.p.m. was about the limit of speed for radial engines, but I have flight-tested the No. 2 Wasp engine without its subsequent improvements at almost 2500 r.p.m., and I have flown a race of 120 miles at 2270 to 2280 r.p.m. when the engine was developing well over 500 hp.

Flight Experience

Wasp engines built on the first experimental contract have been installed in place of water-cooled engines in the Curtiss and in the Boeing single-seat fighting-airplanes. This is an interesting comparison but is not a fair one because the reduction in weight made possible by the air-cooled engine resulted in considerably lowered landing-speeds and the fuselages which were designed for water-cooled engines were not well suited to air-cooled-engine installation. The Wright Apache airplane was designed for an air-cooled engine and its performance is much superior to any of the water-cooled conversions made.

In making comparisons of airplanes, the results must be reduced to some standard basis and by far the most practicable and logical basis is the landing-speed of the airplane. This has a direct bearing on the high speed obtainable. In general, it can be stated that if the permissible landing-speed is increased 1 m.p.h., a gain of 2 m.p.h. can be expected in the high speed.

Flight tests to date have indicated that the water-cooled airplanes converted into air-cooled airplanes show the same high speed as with the water-cooled-engine installation, show a reduction of some 4 to 5 m.p.h. in landing-speed, and show climb and maneuverability distinctly superior to those obtainable with water-cooled engines. The Wright Apache airplane incorporates all the savings and advantages which accrue from the use of an air-cooled engine, and surpasses the standard water-cooled types in all factors which go to make up what is known as performance.

The comparative results already outlined were obtained first at the Naval Air Station, Anacostia, D. C., where flight tests of new types are usually conducted. The Curtiss Hawk airplane equipped with a Wasp engine was then flown out to the Pacific Coast and given some comparative testing by all pilots in a fighting-airplane squadron with the same airplane equipped with water-cooled engines. The consensus of opinion in the squadron was most favorable to the air-cooled engine and checked exactly the reports from the test pilots at Anacostia, D. C.

The Wright Apache airplane was flown in the Free-for-All Pursuit Race at Philadelphia, and demonstrated high speed distinctly superior to all other airplanes using service engines. The two airplanes which were faster, by about 2.5 per cent, were equipped with engines of greater piston-displacement, having compression-ratios of 6.5 to 1.0 and 7.5 to 1.0 and requiring highly doped or blended fuels. Their landing-speeds were higher than that of the Apache airplane by many miles per hour. Incidentally, in racing the Apache airplane, it was found that the engine, while developing 25 per cent more than its rated power ran too cool, which indicated that it should have been cowled-in more closely than it was.

The Wright Type-J engine has carried the greatest part of the Navy's work with small airplanes for the last 3 years. The first engines were installed in small single-seat fighting-airplanes, and are now being replaced by more modern airplanes of higher performance. Before this engine came into service, it was necessary to conduct spotting operations in land airplanes operating from shore bases.

The 200-hp. air-cooled engines made possible a small light two-seat observation airplane which was suitable for operation from battleships and cruisers. Due to their small size and light weight, these airplanes could be catapulted, hoisted-in, and handled aboard ship easily. Their reliability made it possible for them to operate over very rough water with the minimum of hazard. These airplanes made it possible to demonstrate to the fleet the great value of aircraft spotting and short-range scouting-operations. With the development of higher powers and airplanes of superior performance, this use for a 200-hp. engine will disappear as soon as funds are available to provide new materiel. The extensive operation of the Type-J engine has resulted in such improvements and refinements that, due to its reliability, low first-cost and maintenance charges, and to its great ease of maintenance, it has become the ideal training-airplane engine. Many of these engines are now being put into that service.

Superchargers

Much attention has been given in the past and is being given at present to the performance of aircraft at sea-level, particularly to high-speed performance at sea-level. This probably is due to the fact that speed is measured most conveniently at sea-level, but the practice is most unfortunate as it results in a false estimation of the real naval or military value of the airplane. Altitude is a great advantage in all military flying. To a fighting airplane the altitude advantage over the enemy is as vitally important as was the weather gage in the days of vessels of the so-called "frigate" class. For all other types, altitude provides protection from anti-aircraft guns, a temporary gain in speed at the sacrifice of altitude already gained, increased radius of visibility and, at great altitudes, invisibility from the earth's surface. The World War proved that aerial operations will be carried out at ever-increasing altitudes, to make use, to the limit of the materiel, of the advantages so gained. The value of any airplane should be based on its performance at the assumed mean altitude at which it will be utilized.

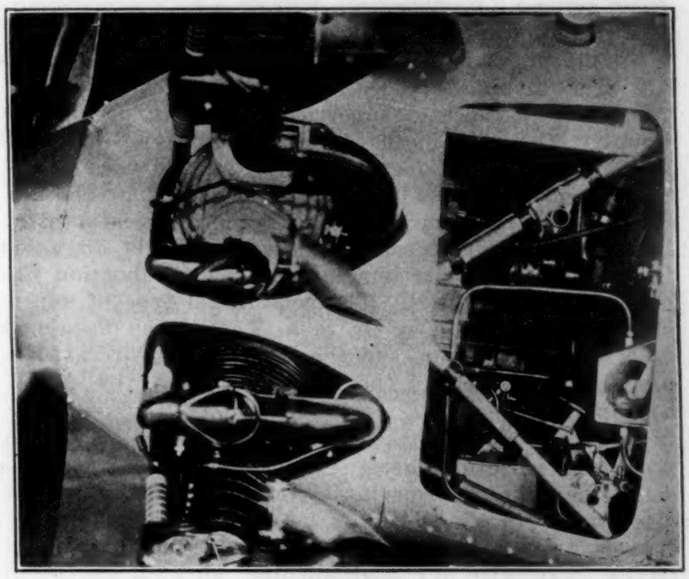


Fig. 4—Accessibility of Accessories
Side Openings in the Cowl of the Apache Airplane Provide Ready Access to All the Engine Accessories from Both Sides of the Fuselage

It seems improbable that much more than minor improvements and refinements are possible with the engines of today. For any very great increase in performance it seems also that a radically new development must be undertaken. Therefore, the most logical and promising field for improvement is in improving the great-altitude output of present engines. Assuming a constant crank-speed, the power developed in the cylinders of an engine is directly proportional to the weight of charge burned or to the air density. With increased altitude, the shaft horsepower falls off more rapidly than does the air density, due to some friction losses being constant. The power absorbed by the propeller is proportional to the cube of the number of revolutions per minute, and directly proportional to the air density; therefore, as the power-input to the propeller falls off faster than the density, the number of revolutions per minute also falls still more and thus reduces the power. Assuming a constant crank-speed, a normal engine develops one-half its sea-level power at an altitude of about 19,000 ft., but

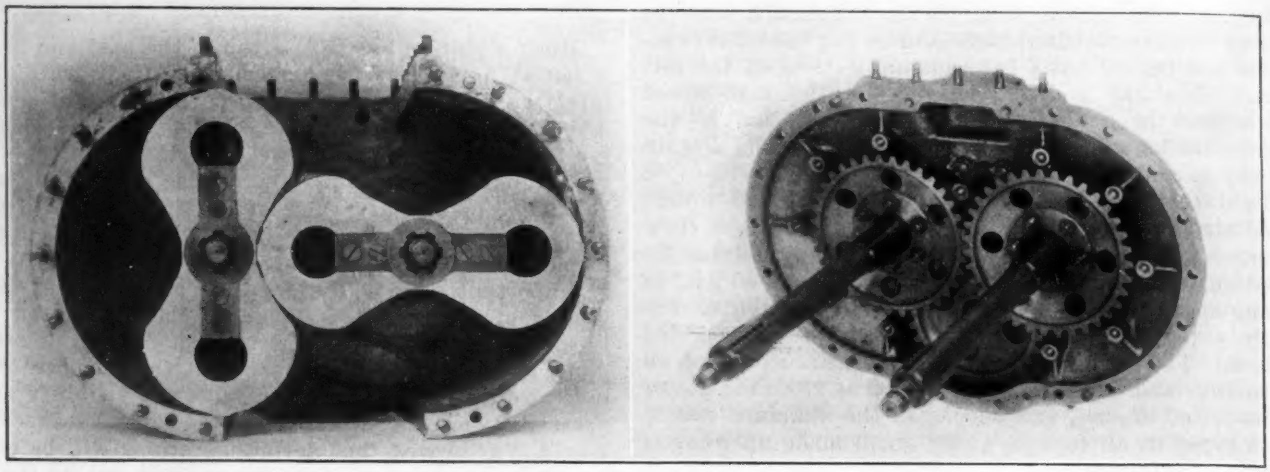


FIG. 5—INTERIOR OF THE ROOTS-TYPE SUPERCHARGER
The Driving-Gears and Shafts of the Rotor Are Shown. Note the Mesh of the Rotors and Their Contour, Which Differs from That of the Customary Commercial-Type Roots Blower.

when driving a propeller, one-half of engine power occurs at a much lower level than that.

To prevent this serious loss of power, superchargers are used to maintain sea-level pressure at the carbureters. Two types of supercharger are in use in this Country, the high-speed centrifugal-fan type developed principally by the General Electric Co. and used by the Army, and the Roots-type blower developed by the National Advisory Committee for Aeronautics and used by the Navy. The subject of supercharging is discussed in the paper on Supercharging Internal-Combustion Engines[7], by C. R. Short. The centrifugal type of supercharger[8] is described by Dr. S. A. Moss in the discussion of Mr. Short's paper, and the Roots-Type Aircraft-Engine Supercharger[9] is the title of a paper by A. W. Gardiner.

Each type has its proponents, and it seems that each type has its useful sphere. No attempt will be made to define their limits or merits, as that would invite endless discussion. In general, it is believed that the impeller type is suitable for low-altitude work but that it is totally unsuitable for high-altitude work unless fitted with some form of variable-speed drive which, of course, adds weight and complication and detracts greatly from its attractiveness. For high-altitude supercharging, an impeller of reasonable size needs to be driven at extremely high speeds. The precessional forces set up in the fan due to rapid maneuvers of fast airplanes would be great. The heating of the charge results in a large loss in volumetric efficiency in the engine and requires an intercooler one-fourth the size of the radiating surface of the powerplant. The greatest heating and power absorption take place at sea-level, where the supercharger cannot be used, and the compressed charge must be re-expanded by some wire-drawing at the throttle at all altitudes below the critical altitude to avoid excessive compression-pressures.

The Roots type of compressor was a commercial product in 1859, when it was manufactured by the P. H. & P. M. Roots Co. of Connersville, Ind., from which company it probably received its name. The Roots blower seems ideally suited for supercharging and, in the form developed by the National Advisory Committee for Aeronautics, has been highly satisfactory. This is illustrated in Fig. 5. Much laboratory work and experimental flight-testing have been done and, at present, a squadron of new airplanes is being equipped with this type of supercharger. These superchargers have cast aluminum-alloy side-casings, heavily ribbed to prevent distortion under load, to permit the use of small rotor-clearances. The rotors are hollow magnesium castings, internally ribbed, and have splined steel-hubs on the shafts. The rotors are carried on ball-bearings, primarily to simplify the lubrication problem. The blower is driven through a flexible coupling at one and one-half to three times engine-speed, depending upon the critical altitude desired. Intake air is drawn in through a duct from outside the fuselage. The discharge is led directly to the carbureter through another duct, which has fitted in it at any convenient point a large bypass-valve, the effective area of which is equal to the cross-sectional area of the duct. The valve is connected either to an extension of the throttle or to an independent lever, and constitutes the complete control of the supercharger. At sea-level, or whenever no supercharging is desired, the valve is held wide-open and the carbureter can get air at atmospheric pressure corresponding to the altitude. The supercharger is then running in the "no-load" condition and is absorbing 1 or 2 hp. to overcome friction and the "fanning effect." As the airplane ascends into air of less density, the valve is regulated to provide the desired degree of supercharging pressure at the carbureter. At any altitude below the critical altitude with the centrifugal compressor, the work done on the air is greater than that done by the Roots-blower type; hence, the power absorbed and the temperature rise of the charge are greater. With a turbine drive, the hot-exhaust collector is very objectionable.

The efficiency of the two types as compressors is approximately the same. For rotary distribution, the centrifugal blower is ideal. It puts back into the mixture the heat absorbed in vaporization of the fuel and, as it is gear-driven, it prevents any increase in manifold depression at high crank-speeds. To illustrate the advantages to be gained by supercharging, a standard Navy shipboard observation-airplane of the UO-1 type fitted with a J-4 engine was equipped with a Roots blower and, as a result, its rate of climb was increased materially at all altitudes above sea-level and its service ceiling was exacty doubled.

STARTERS

The starting of aircraft engines always has been a more or less difficult problem. The size of the engines

[7] See THE JOURNAL, February, 1926, p. 185.
[8] See THE JOURNAL, October, 1926, p. 385.
[9] See THE JOURNAL, September, 1926, p. 253.

is such that a large starting-torque is required. The employment of aircraft is such that quick and positive starting, frequently under very adverse conditions, is necessary. On the other hand, as the starter has no useful function in flight, the application of the starter involves a distinct sacrifice in performance to accomplish starting on the ground or on the water. Various forms of starter have been tried for years with but indifferent results and, so long as the engines were small and were capable of being cranked by hand by pulling through the propeller, starters were not received with much favor. Pulling through the propeller by hand is a dangerous operation at best and even a skilled mechanic of good physique cannot turn the engine past more than one or two compression points, except in the case of small engines having no military value. Electric starters were tried which employed a small motor, driving through a large gear-reduction. The starters themselves gave trouble and they were very destructive of batteries; also, the battery capacity required entailed the use of extremely large and heavy batteries. Therefore, for many years after the World War, engines up to and including the 200-hp. size were started by pulling the propellers when the propeller was accessible. For larger engines and for seaplane work, small hand-starters were used which consisted solely of a hand-crank geared down to the crankshaft.

Compressed-air starters of various types came into extensive use on European engines. These starters consisted of a supply of compressed air stored usually in a small flask that was carried on the airplane, a miniature carbureter in the air-supply line, a distributor driven from a camshaft, and individual pipes leading to check-valves installed in the cylinders. These compressed-air starters have been very efficient so far as starting is concerned but, in this Country, we have been unwilling to accept the multiplicity of piping and valves required and the driving of any unnecessary mechanism from the camshaft.

Starter developments in the United States have taken the form of the inertia starter. These are being built for the Navy at present by the Healy-Aeromarine Bus Co., successor to the Aeromarine Plane & Motor Co., and by the Eclipse Machine Co. in its plant at Hoboken, N. J. These starters employ a hand-crank and a gear-train which drives a miniature flywheel, and a constant-torque slipping-clutch through which the flywheel can transmit its energy to the engine. In operation, the crank is turned by hand until the flywheel is brought up to the required number of revolutions per minute. A man of normal physique should accomplish this in 20 to 30 sec. The gear-reduction is approximately 150 to 1 and the weight of the flywheel is about 4 lb. When the flywheel has been brought up to about 15,000 r.p.m., a tripping device connects the flywheel, through the same gear-train used to drive it, to the constant-torque clutch and, at the same time, engages the starting-dog. At average operating-speeds, the energy stored-up in the flywheel amounts to 5000 ft-lb. or more. The clutch can be set for any desired break-away torque. In small engines, a torque of 400 lb-ft. suffices but, for the largest engines, clutches are set for 750 lb-ft.

By careful arrangement of the gear-train, these starters have been reduced in size to that of the crown of a man's hat and their total weight is between 19 and 25 lb. depending on the model. They are very rugged and reliable. Incidentally, it is indicated that their use will eliminate the necessity for the hand-operated booster-magneto used for starting purposes, which will result in a saving of some 11 or 12 lb. in weight. These starters have been received with great enthusiasm on the part of the operating units.

Ignition

All engines for naval aircraft are fitted with dual ignition, which is necessary from the viewpoint of reliability and consequent reduction in hazard but is especially necessary in large engines because it justifies the slight increase in weight by increasing the efficiency of the engine. For some time after the War, the ignition situation was not entirely satisfactory to the Navy. In the last 3 years new material has been adopted which has given highly satisfactory service. After exhaustive tests carried out by the Navy and checked by independent

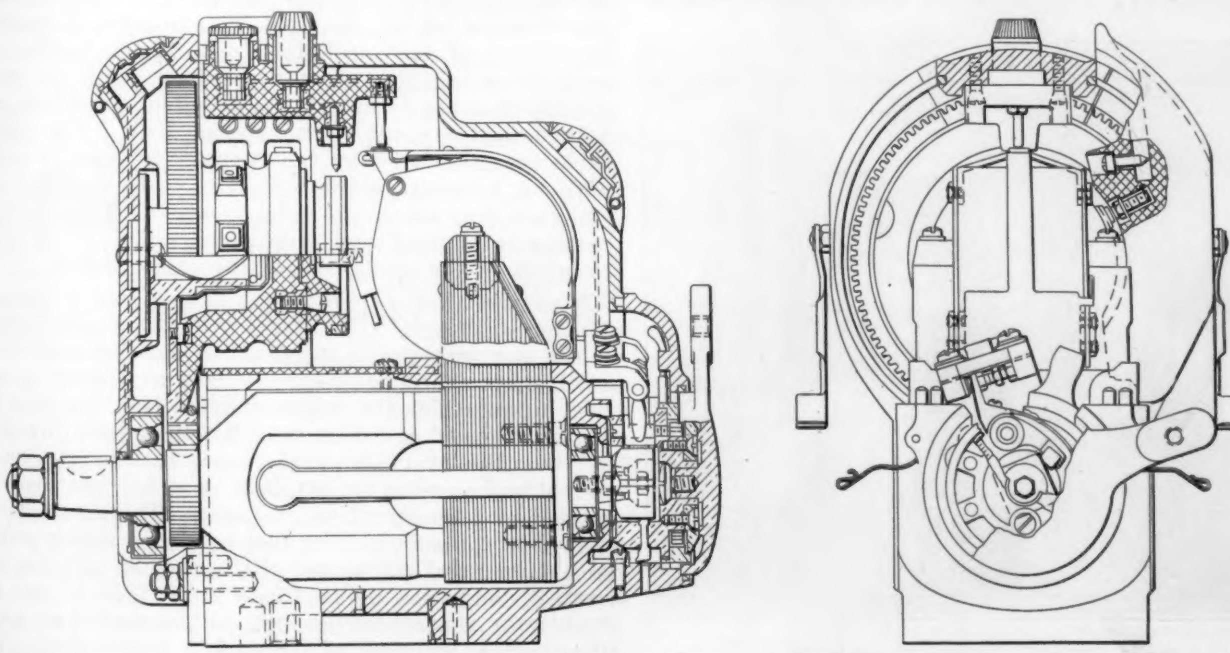


Fig. 6—Scintilla Aircraft-Engine Magneto
The Unusual Feature in This Magneto Is the Rotating Magnet. It Has Been Adopted for Use on All Naval Aircraft Engines except the Liberty-12 Engine

tests by the Wright Aeronautical Corporation, Scintilla magnetos were adopted by the Navy, and a view of the aircraft model of this magneto is shown in Fig. 6. At that time, these magnetos were manufactured in Switzerland, which was the most unsatisfactory aspect of the situation. However, in view of the satisfactory performance of these magnetos in service, enough were imported for the Navy's immediate needs and arrangements were made to have future magnetos manufactured in this Country. It required considerable time to get into production on such a highly specialized instrument, and American-built Scintilla magnetos have only been put into service recently. The American magnetos delivered to date, however, seem to be in all respects equal to the Swiss-built machines and, at present, certain improvements are being incorporated which it is believed will make the American product distinctly superior. These magnetos have been adopted for use on all engines except the Liberty-12 engine which, due to the 45-deg. V-construction, required special ignition. The unusual feature in the Scintilla magneto is the rotating magnet.

The service required of aircraft engines imposes particularly severe demands on the spark-plugs. The engines must be capable of idling for considerable periods and must operate at high brake mean effective pressures. These conditions require the spark-plugs to have an unusually wide temperature-range through which they will operate satisfactorily. This condition is aggravated by the fact that different types of engine cause the spark-plugs to operate at widely different temperatures. The matter of mechanical strength to resist damage by accidental blows from tools and the like is important and, above all, it must be made impossible to blow out a damaged core because the flame emitted through the spark-plug shell would constitute a serious fire-hazard. A spark-plug has been developed by the B. G. Corporation which has given excellent service and, in general, fulfills all the requirements already outlined. The development of this spark-plug was a long process and involved many interesting problems. The manufacturer has produced mica-insulated spark-plugs for years. The plugs were supplied in two types suitable for hot-running and for cold-running engines. A limited number fitted with an extra gap built into the head have been used. I have never been convinced that the extra gap made any material difference in operation. In 1925, the development of a new type spark-plug was undertaken which resulted in two miniature models, shown at the left and at the center of Fig. 7. These small spark-plugs are practically scaled-down editions of the B. G. standard-size spark-plugs, shown at the right, mica-insulated and all-steel except the brass terminal and the copper core-seating gasket. Single and multiple-cylinder tests showed remarkable characteristics. The operating temperature-range is very much wider than for the larger models. Fouling of spark-plugs is unusual, and the spark-plugs clean-up readily when the throttle is opened. It is practically impossible to heat the spark-plugs to preignition temperatures, even under the worst conditions in a single-cylinder Liberty-12 test-engine and, after having given them much more severe test-running and flight tests, these tiny spark-plugs seem almost indestructible. The miniature and the ordinary automobile spark-plugs are compared in Fig. 8.

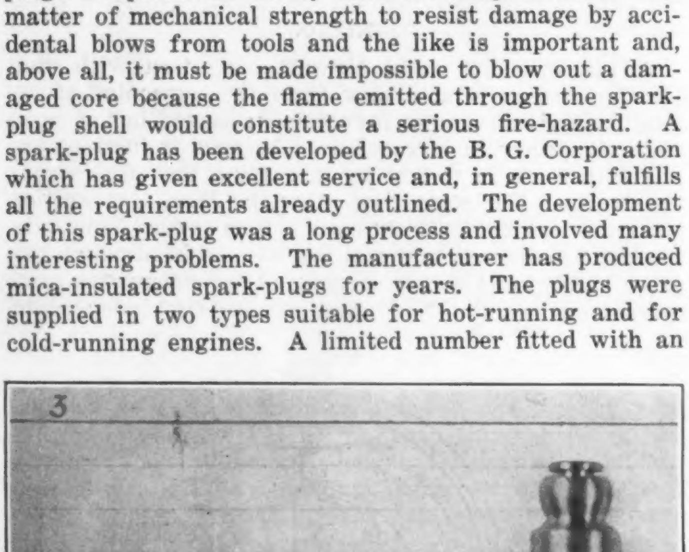


Fig. 7—Aircraft Engine Spark-Plugs
The View at the Left Shows a B. G. Midget Spark-Plug, the Central View Illustrates the B. G. Hornet Type, and the View at the Right Depicts a B. G. Model-1XA Extra-Gap Spark-Plug

Additional advantages accruing from the small size of the foregoing spark-plugs are a weight-saving of 4 lb. when applied to a 12-cylinder engine and increased clearance between the heads of the spark-plugs and other parts of the engine and the cowling. One type, known as the Hornet, is a combination of the standard-size shell with a miniature core, which fits all service types of engine. The other is a full miniature spark-plug with ½-in. thread, 20 threads per in., which is being tested for future use. The small diameter is of great importance in decreasing the spark-plug end-area exposed to radiant heat and in increasing the length-diameter ratio. The latter may make it possible to screw the spark-plug directly into the cylinder-head of an aluminum cylinder without the necessity of fitting a bushing to take the wear resulting from occasional removal. The elimination of the bushing eliminates the junction resistance to heat-flow between the bushing and the cylinder metal.

To complete the ignition system, a new type of high-tension cable has been adopted which is giving excellent results. Ignition cable is subjected to a certain amount of heat and oil vapor and to frequent kerosene baths during cleaning of the engine. This results in rapid deterioration of the insulation. The result is that small leaks occur in a very short time which, while not serious enough to cause failure of the ignition, constitute a fire hazard in the event of a gasoline leak. The ignition cable, manufactured by the Acme Wire Co., is covered with an enameled-braid protective-coating which looks and feels very much like patent leather. This protective coating is oilproof and waterproof and is very pliable. It increases the useful life of the cable greatly.

Compression-Pressures

The compression-pressure which can be used in aircraft engines depends upon the service operating-conditions under which the engine will function, the fuel used, the crank speed and, to a considerable extent, the design of the cylinder. The first consideration involves the weight and speed of the airplane as well as the load to be carried and the duration of flight. This consideration cannot be controlled. The fuel used is a widely controllable factor and the proper choice of fuel permits using compression-ratios up to 7.5 to 1.0. This is not practicable for general-service use, as the matter of supply, distribution, and cost of the fuel is prohibitive. These factors also militate against the use of especially cut fuels from selected fields, such as are in general use

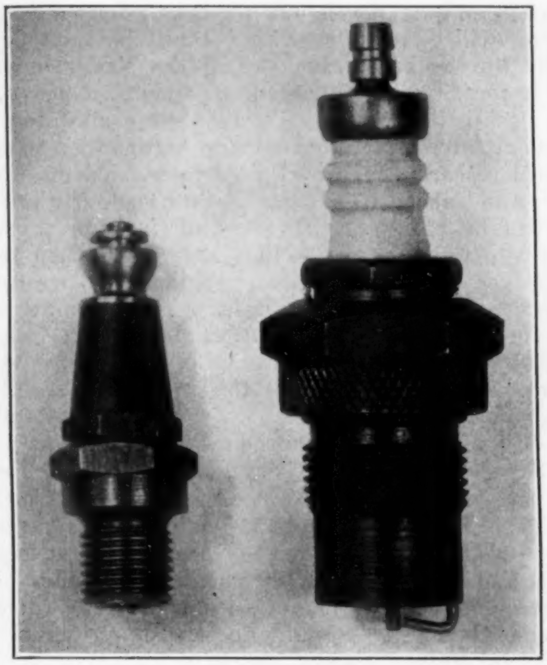


Fig. 8—Comparison of Spark-Plug Sizes
The B. G. Midget Spark-Plug Is Shown at the Left and an Ordinary Automobile Spark-Plug Is Illustrated at the Right

abroad. It is well recognized that great improvement is possible in the quality of the gasoline furnished to the service, but it has been the unvarying policy of the Navy Department to require its aircraft engines to operate satisfactorily on a grade of fuel which is readily obtainable in any quantity and which can be produced in the quantities required for war. For special purposes and to take care of unusually severe operating-conditions, gasoline is doped with "ethyl fluid" or blended with motor benzol. The anti-detonating qualities of even a poor grade of gasoline can be increased greatly by the proper proportions of either benzol or ethyl-fluid. For service engines, we now use compression-ratios varying from 5.10 to 5.44. Geared engines which operate at high crank-speeds have a compression-ratio of 5.9 to 1.0. Improvements in the design of cylinders which provide better forms for the combustion-chambers and eliminate hot-spots have slightly more than compensated for the gradual decrease in the quality of fuel which has occurred during the last several years.

During the War and for some time afterward, an air-pressure system was used to supply fuel to the carbureters. A small engine-driven air-pump maintained a pressure of 2 to 4 lb. per sq. in. on the tanks. Air pressure on the tanks constituted a very serious fire-hazard in the event of a crash. The large tanks must be of very light construction and are therefore fragile. In the case of a burst tank, the air pressure caused gasoline and vapors to be sprayed around in the debris with almost a certainty of some of it finding its way to the hot exhaust-stacks. At present, it is general practice to lead the fuel from the tank through a hand-pump, which can be operated by the pilot in case of necessity, to a very small engine-driven fuel-pump. This pump delivers the gasoline directly to the carbureters at a pressure of from 4 to 5 lb. per sq. in. A small spring-loaded valve is used to regulate the pressure and the overflow is returned to the tank. This overflow cannot be returned to the suction side of the pump through a regurgitating valve because, at great altitude, the fuel becomes highly volatile and many bubbles are formed in the supply line. Putting this back into the pump-suction results in vapor-binding of the pump.

Fire Hazard

The fire hazard probably is by far the most terrifying of all hazards encountered in aviation. Fires in the air are almost invariably the result of a broken or leaking fuel-line, the leakage from which becomes ignited by some leak in the ignition system. The heated exhaust-pipes and the products of combustion are not serious sources of ignition in flight due to the high velocity of air-flow around the exhaust area. Fires therefore occur in the engine compartment or in the first cowled-in bay of the fuselage. All airplanes have a metal or metal-and-asbestos fire-wall built into the fuselage in the wake of the engine and carry a pressure fire-extinguisher. This is illustrated in Fig. 9. The fire-extinguisher has a capacity of about 1 qt. of carbon tetrachloride and sufficient compressed-air to spray it around the engine compartment.

In its latest form, the fire-extinguisher is built in the form of a cylinder with a central tube. The tube contains air compressed to approximately 100 lb. per sq. in. The outer space contains the tetrachloride fluid. Two needle-valves mounted in the head are connected to a yoke which is operated by a quick-acting thread. The

Fig. 9—Means of Fire Prevention
All Airplanes Have a Metal or a Metal-and-Asbestos Fire-Wall Built into the Fuselage and Carry a Pressure Fire-Extinguisher of the Type Shown. The Extinguisher Contains about 1 Qt. of Carbon Tetrachloride and Eufficient Compressed Air To Spay It around the Engine Compartment

valve-actuating lever is arranged for manual control by the pilot. When the valves are opened, compressed air is admitted to the liquid compartment and the liquid outlet is opened to discharge the fluid over and around the engine. The extinguisher is mounted as close to the engine as possible to reduce the amount of piping required, as it is more convenient to install a long-distance operating-device than to install a long discharge-pipe.

The results of a large number of actual crash-tests made at McCook Field, Dayton, Ohio, indicate that the probable source of ignition following a crash is the hot exhaust-pipes. This condition has been eliminated so far as possible by the use of individual exhaust-stacks exposed to the slipstream. The danger of fire in this case is not confined to the gasoline, as the temperature of the ignition point is sufficient to ignite the hot oil spilled from a broken crankcase or a rupture in the oil system. Incidentally, it is indicated that in the case of hot-plate ignition, lubricating-oil is more likely to be ignited than gasoline.

Gearing

The question of gearing airplane-engines is still indeterminate. Gears are used to operate the engines at high crank-speeds and, therefore, to obtain the maximum power from any given piston-displacement, and, at the same time, to permit the use of large slow-speed propellers to obtain maximum efficiency at low air-speeds. The use of gearing introduces many serious problems which have not been solved. Gearing adds weight and complication to the engine, and this requires additional weight in the structure to carry it. Much more serious, however, is the multiplication of the torque reaction on both the engine and the airplane structure. Great difficulty and many failures have been encountered in the mounting of geared engines. At present, it is indicated that the strengthening of both the engine and its mounting to take care of the greatly increased torque due to the slow-speed propeller will add much more weight. This, coupled with the weight added to the engine by gearing and the great increase in propeller weight, will offset the advantages of the geared installation. Gearing must be considered in the experimental stage at present, and I strongly believe that equally good results without any complications can be obtained by the use of greater piston-displacements and lower crank-speeds which will permit the use of large-diameter and reasonably efficient propellers.

It seems, then, that if the geared engine is destined to be a valuable development it must take the form of a really high-speed job and the gear-reduction must be materially greater than the 2 to 1 ratio used today. If such a scheme is worked-out satisfactorily, it probably will have to begin with the design of an engine different from our accepted types, in which any large increase in crank speeds would result in prohibitive piston-speeds and inertia-forces.

Heavy-Oil Engines

The possibilities of heavy-oil solid-injection compression-ignition engines for aircraft use have always provided an attractive and alluring field of endeavor. No satisfactory engine of this type has been produced, but a considerable amount of work has been done on the problem and it has furnished a great amount of valuable information. From the results obtained to date, it appears that the heavy-oil engine is most attractive for lighter-than-air craft, and it is believed that a successful engine for large rigid airships eventually will be the starting-point in development. It is possible that these engines will be made suitable for heavier-than-air craft.

The Bureau of Aeronautics of the Navy Department has fostered research and development in heavy-oil-engine design in two ways. Funds were allocated to the National Advisory Committee for Aeronautics to conduct general research-work on the various problems involved. Much was learned from some studies made of the characteristics of the solid injection of fuel, principally in respect to the penetration of the fuel jet when the fuel is sprayed into the chamber against the pressure required for ignition. Tests were also made on a single-cylinder engine. A Liberty-12 engine-cylinder was used for this work which had a special piston designed to give a compression-ratio of 11.4 to 1.0. The shape of the combustion-chamber of this cylinder was not suited to solid-injection work, which added complications and detracted somewhat from the results attained. No difficulty was experienced with the metering or injection of the fuel. Tests were made at various speeds from 400 to 1850 r.p.m. The specific fuel-consumption at moderate speeds and power was as low as 0.3 lb. per i.hp. Excellent economy could be maintained up to 1730 r.p.m., but on reduced power. Specific fuel-consumption increased rapidly for higher powers. Tests of high speed and high power were hampered seriously by the fact that the piston would not withstand continued running under those conditions. The engine idled well at 400 r.p.m.

About 2 years ago, the Navy also entered into a contract with A. C. Attendu, of Montreal, Canada, for the construction of a two-cylinder solid-injection engine[10]. This engine has been subjected to much test running. It did not pull the power expected of it and at high speed and power the fuel consumption was not good. The principal difficulties encountered were due to mechanical defects, aggravated by the very poor balance of a two-cylinder engine. This engine idled at 300 r.p.m. with regular firing and has been operated at 1800 r.p.m. The fuel consumption at reduced power was excellent and the engine was characterized by phenomenal acceleration and flexibility. Tests are still being conducted on the engine, which may yet form the basis of a valuable development.

The solid-injection engine lends itself most favorably to rigid-airship work. In these ships fuel must be carried in the envelope and the danger of vapor pockets is greatly reduced by the use of heavy oil. The weight of the engine proper is not as important in the case of the rigid airship as in the case of the heavier-than-air craft because, in the former, the ratio of engine weight to total weight is very much less. The employment of airships requires great cruising-range but very seldom requires full speed. As the total weight of fuel carried is greatly in excess of the total engine-weight, fuel economy becomes of utmost importance and the exceedingly low specific fuel-consumption of the solid-injection engine at reduced powers will be of the first importance.

Steam Powerplants

Many inventions are received which have to do with steam powerplants for aircraft. On first thought, this may appear attractive in the large power-units. The whole project, however, has been most carefully investigated and, in comparison with the internal-combustion engine, it can be stated that the steam powerplant is not worthy of serious consideration in any form which has been devised to date. The steam powerplant cannot compete with the internal-combustion engine in regard to the most important considerations of pounds per

[10] See The Journal, February, 1926, p. 214.

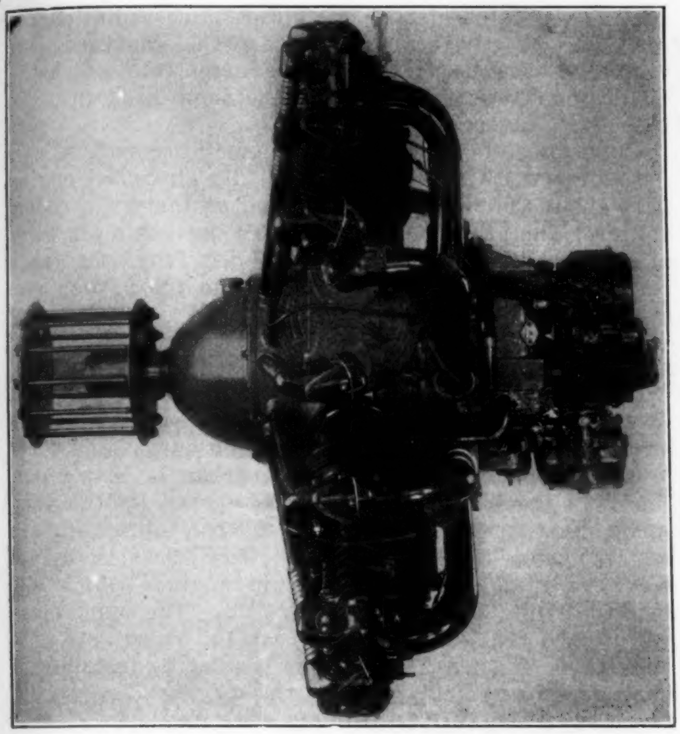


Fig. 10—Pratt & Whitney Hornet Engine
This Engine Is an Oversize Wasp Engine, the Piston Displacement Being about 25 Per Cent Greater

horsepower and fuel consumption. It can be shown that even the most efficient steam powerplant cannot develop its power on a specific fuel-consumption of 0.5 lb. per hp-hr. The weight of a steam generator would be equal to or greater than the total weight of an internal-combustion engine, even with the utilization of a flash-plate boiler. One of the requirements of an aircraft powerplant is great flexibility and perfect control throughout its entire range of speed. This is difficult of attainment in steam powerplants except through the use of very delicate and intricate mechanism. Another feature which is prohibitive in itself is the condenser. A condenser would be absolutely necessary, because an airplane could not carry sufficient water to run for any length of time non-condensing. The use of the lightest possible condenser of the wing-radiator type would add approximately 2 lb. per hp. to the powerplant weight; but, for such a condenser to be reasonably efficient, its area would become so large that the total wing-area of the airplane would be woefully inadequate, even assuming that the lower surface would be as efficient as the upper surface, which assumption could not be even approximated in practice. To obtain the highest efficiency and steam economy from the engine, a turbine probably would be used. The efficiency of a turbine is dependent upon a good vacuum. Even if a suitable condenser could be devised, the condenser would depend upon atmospheric air to carry off the heat. With the airplane operating in warm atmosphere, the temperature difference of steam and air would become zero at such a temperature that a high vacuum is out of the question. Eliminating the condenser from the problem, it is estimated that a steam powerplant would weigh 5 to 6 lb. per hp. and that the fuel consumption would be approximately double that obtainable in an internal-combustion engine.

Until recently, commercial aviation has been compelled to use surplus stocks of war-time materiel almost entirely. This resulted from the disposal of the materiel at prices which would not, in many cases, cover the cost of distribution of new materiel, and from the prohibitive cost to an infant industry of undertaking new development. Consequently, commercial aviation has been struggling under the handicap of old, inefficient and obsolete equipment, particularly powerplants. This unsuitability has been partly compensated for by the ridiculously low cost. The last 18 months has marked the dawn of the era of new and vastly better commercial equipment.

As funds became available for development and purchase of new equipment, the Navy took its problem and its needs to the industry. Sometimes it has been necessary to foster new development with financial aid through "experimental contract", where the cost involved has been greater than the industry could stand. Often the materiel has been developed for the Navy in response to the need, with business ahead for the most successful article. The results of this policy have been (*a*) a condition of stability in an industry which, without it, would have been reduced to a chaotic state if it did not perish; (*b*) a steady progress in engine design and engine building resulting in a string of excellent powerplants produced to fit naval needs; and (*c*) one engine to date which has found much favor with commercial users and in the near future a line of engines which should fill any commercial requirements as well as the requirements of the Navy.

Summary

The first engine adopted after the War was the J-1 in the 200-hp. field. This soon supplanted the American versions of the Hispano-Suiza engine. Its development and use in naval aviation produced an excellent, reliable powerplant, and quantity production, speaking in air-

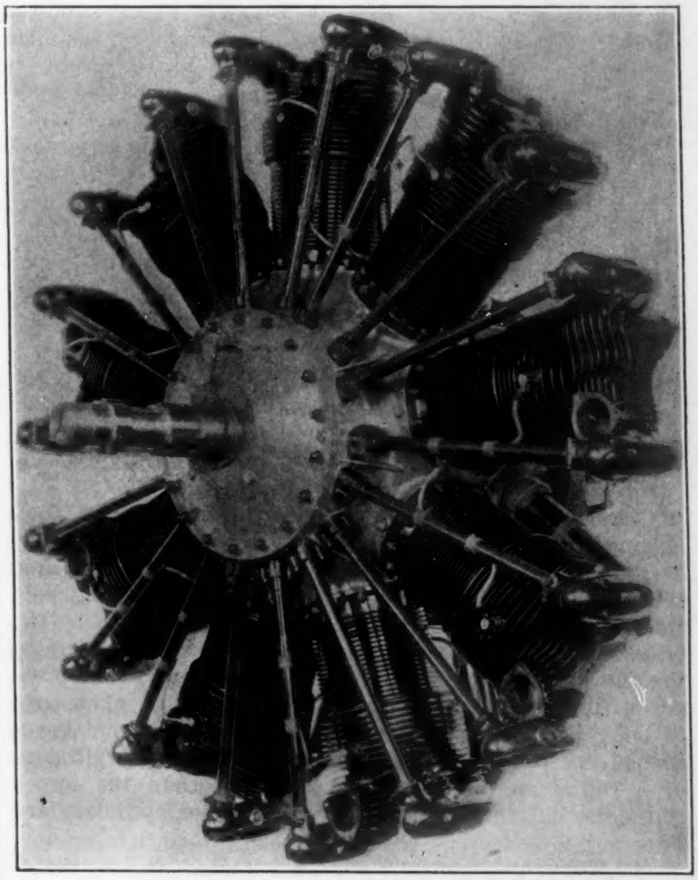


Fig. 11—Wright Model R-1750 Engine
This Radial Air-Cooled Engine Is Known as the Cyclone and Is a Recent Development

craft-quantity terms, brought the price within reach of civilian operators. While the first cost was still much higher than the prevailing price of old water-cooled engines, many were sold commercially. People evidently began to realize that it costs something to carry unnecessary weight and that it is the ultimate cost of engine hours that is important.

The Wright Model-T engine, of 550 to 600 hp., was developed to replace the Liberty-12 engine and to supply the demand for more power in larger airplanes. Many Model-T engines are now in service and are in great favor with the operating units. Installed in very large airplanes which carry heavy loads, they are required to operate at an unusually high percentage of their maximum output; yet it is not unusual for them to go 375 and 400 hr. between overhauls. The Pratt & Whitney Wasp engine has had ample flight-service to demonstrate its excellence in the 400 to 500-hp. field. The Hornet engine, made by this company, is shown in Fig. 10. The two Packard engines in various forms are adaptable to many types of airplane requiring from 450 to 800 hp. Inverted, the smaller engine replaces the Liberty-12 engine in the Loening amphibian airplane. Upright with direct-drive, it is used in fighting airplanes. Geared, it is used in the PN-10 airplanes where it replaced the Wright Model-T engines of the PN-7 airplanes and delivers the same power with several hundred pounds less weight. The larger model is being used to replace the Model-T engines in bombing airplanes, where it delivers 200 hp. more with no increase in weight. While the newer water-cooled engines are being produced for immediate needs, two new large radial air-cooled engines are running on the dynamometers at Paterson, N. J., and Hartford, Conn. The Wright engine, which is illustrated in Fig. 11, is an outgrowth of the 450-hp. Model P-2, a limited number of which are being installed in airplanes at present. The Pratt & Whitney engine is an oversize Wasp engine. Both engines have had sufficient testing to warrant a prediction of their success.

War is a game in which the Devil takes the hindmost. Preparedness may be prevention; it may be the cure. Whatever it is, engines will be needed and engines there will be.

THE DISCUSSION

QUESTION:—What has been the development of two-cycle engines?

LIEUT. C. C. CHAMPION, JR.:—To my knowledge, nothing has been done in the United States toward developing two-cycle engines. Much interest has been shown and great activity has been evidenced abroad, particularly in France and in Germany, but nothing practical has resulted from it.

QUESTION:—How is lubrication accomplished in a fuel-oil engine?

LIEUTENANT CHAMPION:—Lubrication is accomplished by full pressure-feed. The lubricating-oil is drawn from the supply tank and forced by a service pump to the crankshaft, the main bearings, the crankshaft bearings, the camshaft, the pistons and the piston-pins under pressure. The cylinder-walls and piston-pins are taken care of entirely by splash lubrication in a conventional gasoline aircraft-engine. It seems that the lower cylinders of a radial engine would get more oil than the upper cylinders, but that is not true. The upper cylinders are just as well lubricated as the lower. One radial engine scavenges directly from the bottom of the crankcase. One of the new engines has a small oil-sump into which the oil drains. It is pumped from the sump back into the tank by a scavenger-pump.

QUESTION:—Is a large quantity of oil needed?

LIEUTENANT CHAMPION:—No. The air-cooled engine uses about the same quantity of oil as the water-cooled engine. The grade of oil for winter use has a viscosity of about 80 to 85 Saybolt sec. at 212 deg. fahr.; the grade for summer use has a viscosity of 90 to 100 Saybolt sec. at 212 deg. fahr.

QUESTION:—How does the amount of carbon trouble in the radial engine compare with that in other types?

LIEUTENANT CHAMPION:—It is about the same, but we have no carbon-accumulation trouble with any of the aircraft engines, which operate at high output and form practically no carbon. The soft carbon is blown out. The only trouble due to carbon is caused by the very small quantity that is picked up by the lubricating-oil, but we change the lubricating-oil every 15 hr. of flying. We have trouble with the airship engines which use roller-bearings for the connecting-rods. The connecting-rod big-end bearing is a roller-bearing, which acts as a centrifuge. That has been taken care of by installing a small centrifuge and changing the oil more frequently. These small centrifuges are very effective.

QUESTION:—What is a centrifuge?

LIEUTENANT CHAMPION:—It is an instrument that operates on the same principle as that of a cream separator; it is simply a small cup which revolves at a high rate of speed while the oil is passing through it. Any dirt or carbon is thrown to the outside and held there by centrifugal force, and the clean oil pours down through the center. We have no dilution troubles.

CHAIRMAN ARTHUR NUTT[11]:—Most of these air-cooled engines that are being used today are two-valve engines which do not develop as great a mean effective pressure as do the water-cooled engines. But that is compensated by the use of the centrifugal supercharger such as is used in the Wasp engine. Engine-speeds are being kept low at present but they will possibly increase later. We will be able to obtain remarkably high engine-speeds with these new air-cooled engines, which can only be equaled in water-cooled engines by the use of supercompression and exceedingly high crankshaft-speed. The supercharger in the form of a centrifugal blower no doubt is very much lighter than is the other type. The Roots blower occupies much greater space and that is probably one of the facts that escapes those who are in favor of using the Roots blower in airplanes.

QUESTION:—How does the balance of a radial engine compare with the balance of a so-called rotary engine?

LIEUTENANT CHAMPION:—The radial is practically perfectly balanced by the use of counterweights on the crankshafts. The counterweights balance the crankpins, the crank cheeks and the big end of the master-rod. The rotary engine has a limitation that I believe effectively limits it to sizes of about 100 to 125 hp. A centrifugal force is set up by the normal revolving mass. Many 90 to 100-hp. rotary-engines were used in small airplanes during the War and, when the airplane was turning, the centrifugal and the precessional forces set up in the entire engine caused it to act as a gyroscope. If an attempt were made to use 500-hp. rotary-engines in airplanes, the airplanes would be unmanageable. They could fly straight-away, but they could not turn.

[11] M.S.A.E.—Chief engineer, engine division, Curtiss Aeroplane & Motor Co., Inc., Buffalo.

The Single-Sleeve-Valve Engine

By W. A. Frederick[1]

Metropolitan Section Paper *Illustrated with* Charts, Diagrams and Photographs

ABSTRACT

SIMPLICITY is the keynote of the only two types of sleeve-valve engines that have stood the test of time, namely, the double-sleeve, or Knight, engine and the single-sleeve, or Burt-McCollum, engine, the latter type being the subject of this paper. After noting the vicissitudes through which the single-sleeve-valve engine has passed since its first introduction in 1911 and outlining the patent situation, the author describes the mechanical construction of the valve and the sleeve-driving mechanism, discusses the inherent advantages of the characteristic twisting-movement of sleeve-valves, points out the advantages of a detachable head for each cylinder explains the principles underlying the determination of the size, shape and number of the ports and tabulates the average timing-practice of single-sleeve-valve engines. He states that the chief advantages of the single-sleeve-valve engine are sustained operating efficiency, good power-output, and silent operation. Sleeve valves obviate the grinding-in of the valves, the ingress of unwanted air through worn valve-guides, the distortion or sticking of the valve, the adjustment of clearance, the breakage of valve springs, and frequent decarbonization. Rapid opening of the ports, the type of port opening obtained, positive timing, unobstructed intake passages, and increased compression-ratio all contribute to good power-output. Other features of the single-sleeve-valve engine are said to be silence, favorable comparison in weight with that of the poppet-valve engine; added strength and rigidity due to the depth of engine body and shortness of the sleeve-valve cylinder, when a separate cylinder-block is used, allowing the use of aluminum; lubrication by a pressure-feed system of orthodox design; and freedom from detonation on account of the absence of hot exhaust-valves. In the appendix is given a simple method for determining quickly the size and the arrangement of the ports in this type of engine.

A GLANCE through the patent reference files will convince one that much time and thought have been given to the design of valves and valve-operating mechanisms for internal-combustion engines, the predominating inventive thought seeming to be that of replacing the conventional poppet-valve with a valve of different type, positive and quiet in action. Thus, we have rotary valves, piston-valves, cuff valves, and sleeve valves. Sleeve valves have probably received more consideration than any of the other types but most of the sleeve types patented seem to have failed, or would fail commercially, because of complication, the mechanism for imparting the desired motion to the sleeve being so elaborate that the designs are outside of the sphere of practical production. Simplicity is the keynote of the only sleeve-valve engines that have stood the test of time: the double-sleeve or Knight engine, and the single-sleeve or Burt-McCollum engine. The latter type forms the subject of this paper. A general description of the single-sleeve-valve engine will, doubtless, prove of interest at this time, inasmuch as there is every indication of intensive production of the engine in this Country. Fig. 1 shows the left-hand view of an eight-cylinder Continental single-sleeve-valve engine and Fig. 2 the right-hand view of the same engine.

[1] M.S.A.E.—Vice-president and chief engineer, Continental Motors Corporation, Detroit.

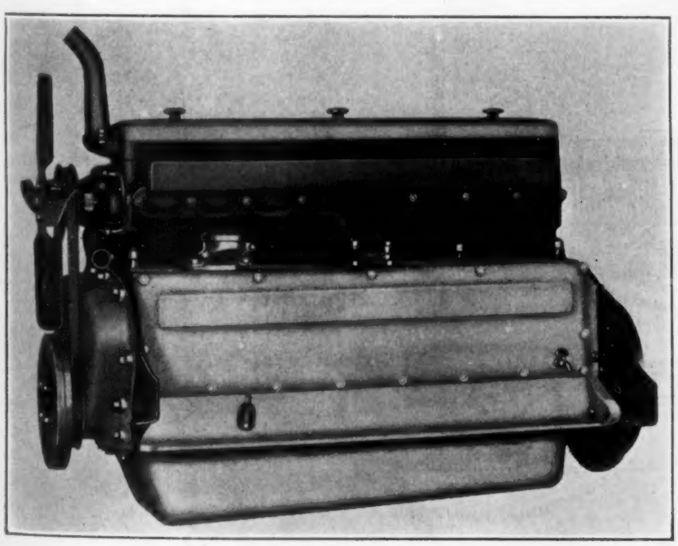


Fig. 1—Left-Hand View of Eight-Cylinder Continental-Type Single-Sleeve-Valve Engine

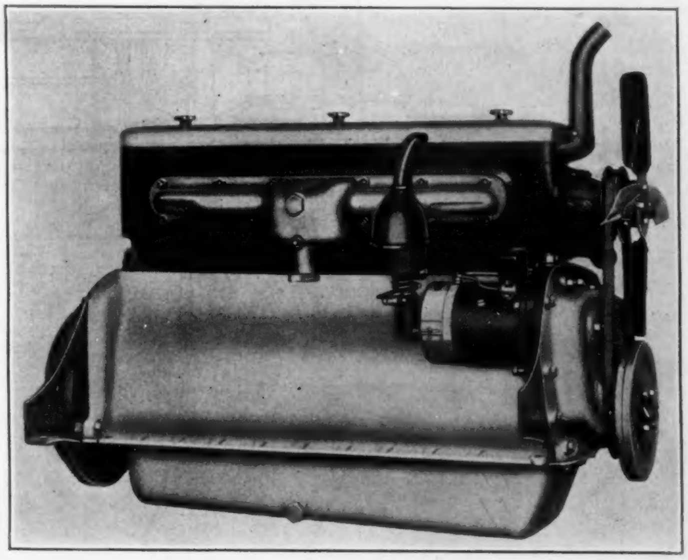


Fig. 2—Right-Hand View of Eight-Cylinder Continental-Type Single-Sleeve-Valve Engine

Development of the Single-Sleeve-Valve Engine

First, let us review briefly the historical aspect and so dispel any notion that the single-sleeve-valve engine is something new and untried. In the year 1911, after about 2 years of research work, Argylls, Ltd., of Alex-

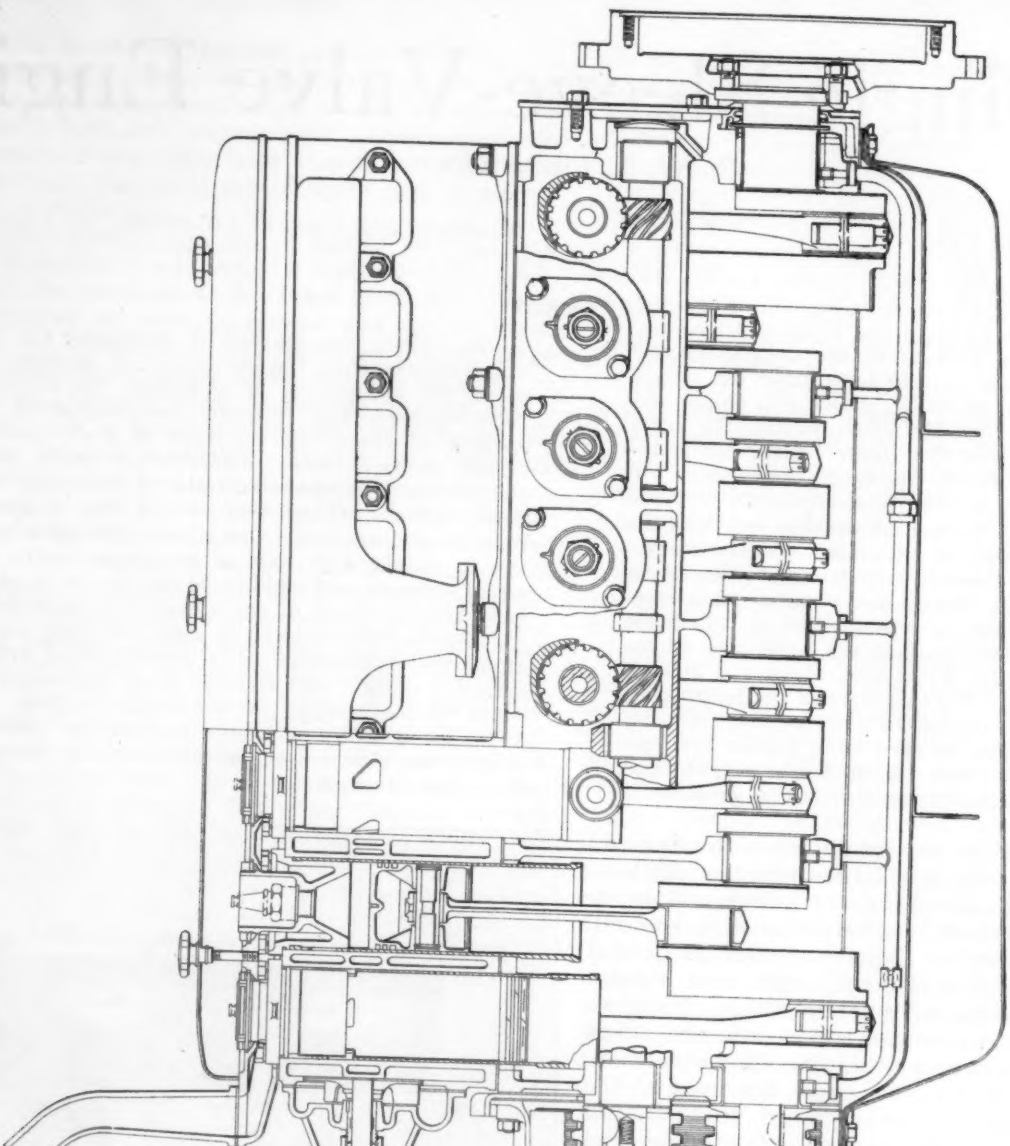


Fig. 3—Cross-Sectional View of Single-Sleeve-Valve Engine

The Crankshaft, Connecting-Rod and Piston Are of Conventional Design. The Essential Difference Lies in Substituting a Single Valve of Cylindrical Form for the Usual Poppet-Valves

andria, Scotland, announced the introduction of a chassis equipped with the Burt-McCollum engine. The car found a ready market, the public's faith in the new type of engine being strengthened, no doubt, by their knowledge and appreciation of the pioneer work of C. Y. Knight, whose double-sleeve-valve engine had, at that time, been in production at the Daimler Motor Co., Coventry, England, for more than 2 years.

During the years 1909 to 1914, Argylls, Ltd., held a monopoly on the single-sleeve-valve engine and manufactured it for their exclusive use. About a month before the outbreak of the war, the Argylls concern had the misfortune to be placed in receivership, with the result that the patent rights reverted to the inventor, Peter Burt.

Work on the engine was practically at a standstill during the war years, 1914 to 1918, but soon after the Armistice the patents were purchased outright by Wallace, Ltd., of Glasgow, who placed on the market a series of stock automobile-engines and granted licenses to other companies for the manufacture of industrial, marine and motorcycle engines, both air and water-cooled, so that it was not until 1919 that the single-sleeve-valve engine was placed in the open market.

Last year, the Continental Motors Corporation negotiated a deal that resulted in their obtaining the world's rights to manufacture and license the single-sleeve-valve engine under the Burt-McCollum patents.

The Patent Situation

It may not be out of place to comment briefly on the patent situation, as we are often asked what is the life of the patent and what does it cover. Burt's original patent was filed on Aug. 6, 1909, and was accepted on Aug. 8, 1910. A 4-year extension was granted last year, so that the date of expiration in Great Britain is Aug. 5, 1929. Application for an equivalent United States patent was filed on Aug. 3, 1910, and was granted on July 22, 1919, thus giving an expiration date of Dec. 3, 1936. Perhaps the broadest claim contained in the United States patent is that which reads:

> A mechanism for the purpose specified comprising a main cylinder having intake and outlet ports near its head, a piston-enclosing cylinder movably fitting within said main-cylinder to act as a valve and having intake and outlet ports, and movable, for bringing the respective ports into alternating registering relation therewith, a piston reciprocating within said enclosing cylinder, and means for imparting synchronous longitudinally reciprocating and oscillating movement to said piston-enclosing cylinder, the range of longitudinal movement being less than the piston movement and greater than the longitudinal dimension of the ports.

J. H. K. McCollum's patents, which were assigned to Argylls, Ltd., and others, consist of a sleeve outside the main cylinder, instead of between the cylinder and the piston, and two operating-mechanisms for imparting the reciprocating and oscillating movement to the sleeve.

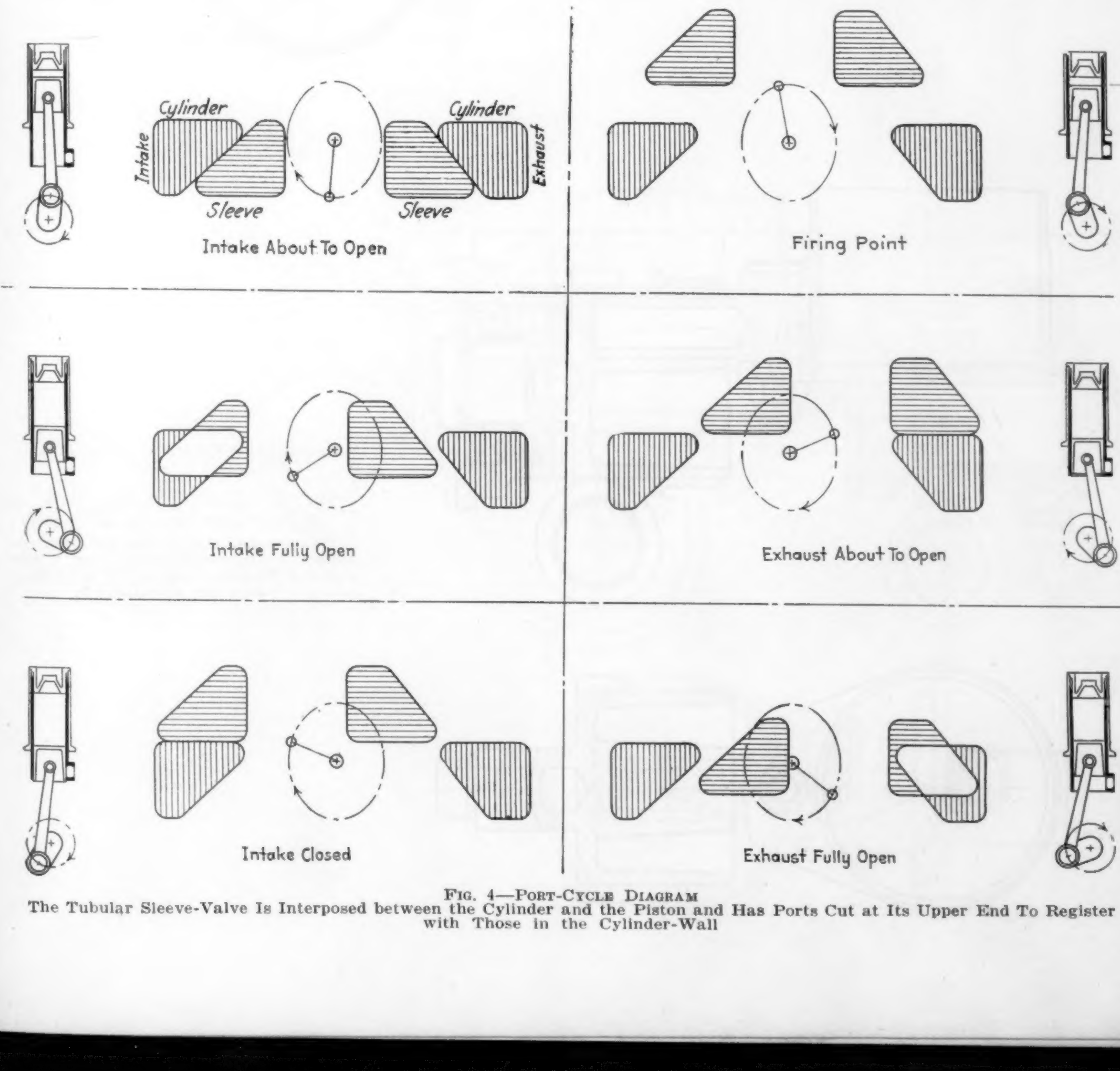


Fig. 4—Port-Cycle Diagram
The Tubular Sleeve-Valve Is Interposed between the Cylinder and the Piston and Has Ports Cut at Its Upper End To Register with Those in the Cylinder-Wall

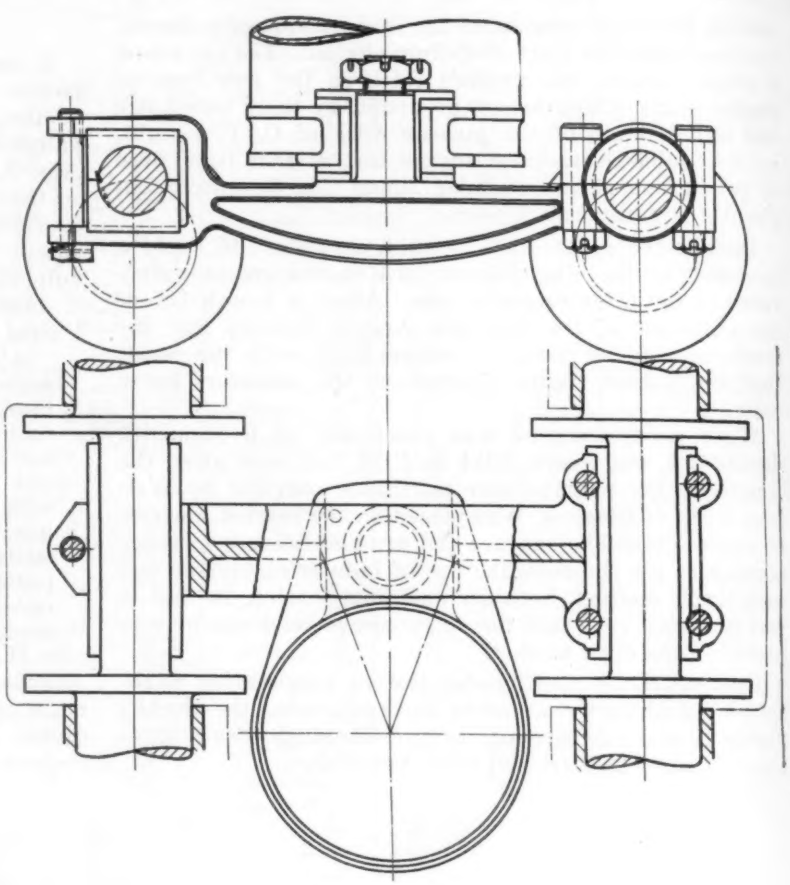


FIG. 6—SLEEVE-VALVE DRIVING-MECHANISM USED BY PICARD-PICET ET CIE, OF SWITZERLAND

This Mechanism Is Rigid and Practically Wearless, But Has the Disadvantage of Being Much Too Heavy, the Placing of the Sleeve Lugs between the Cylinders Adding Considerable Length to the Engine

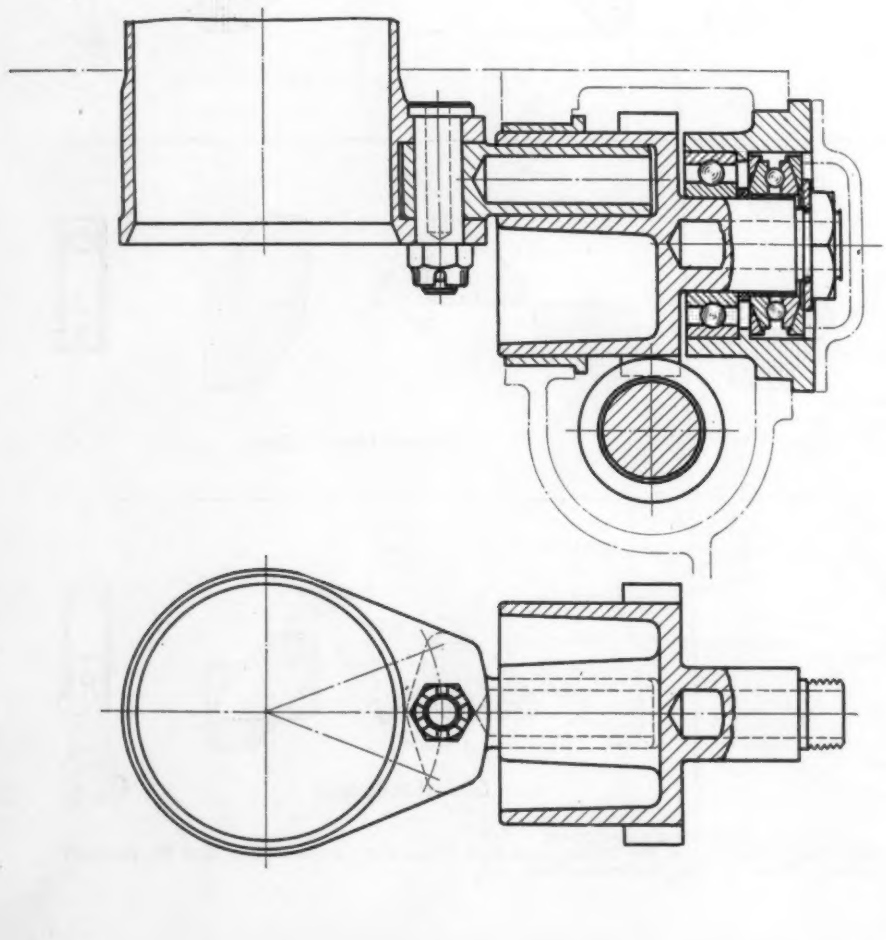


FIG. 5—ORIGINAL ARGYLL TYPE OF SLEEVE-VALVE DRIVING-MECHANISM

This Mechanism Works Satisfactorily, But Is Somewhat Heavy and Costly, owing Partly to the Use of Ball-Bearings and Ball-Thrusts

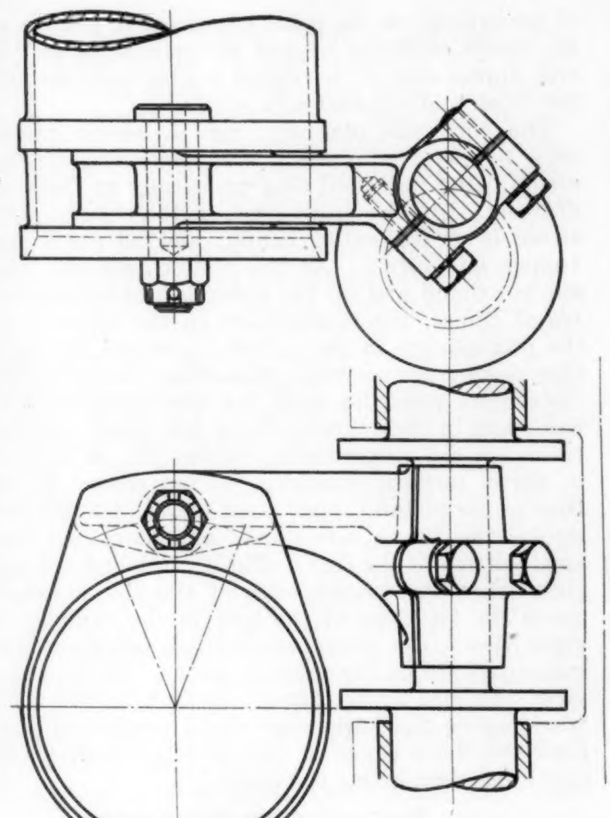


FIG. 7—SLEEVE-VALVE DRIVING-MECHANISM FIRST USED ON THE 1919-MODEL ARGYLL "MARK A" ENGINE

This Is Known as the Link-Drive. It Is Lighter and Cheaper Than That Shown in Fig. 6, But Is Obviously Inferior Mechanically. The Necessary Lengthening of the Engine and the Fact That the Driving Mechanism Must Be Assembled in Its Position in the Crankcase Are Disadvantages; But an Advantage That Should Not Be Overlooked Is the Coupling Effect of Driving Each Sleeve from a Common Valve-Crankshaft, So That the Valve-Timing Is Foolproof

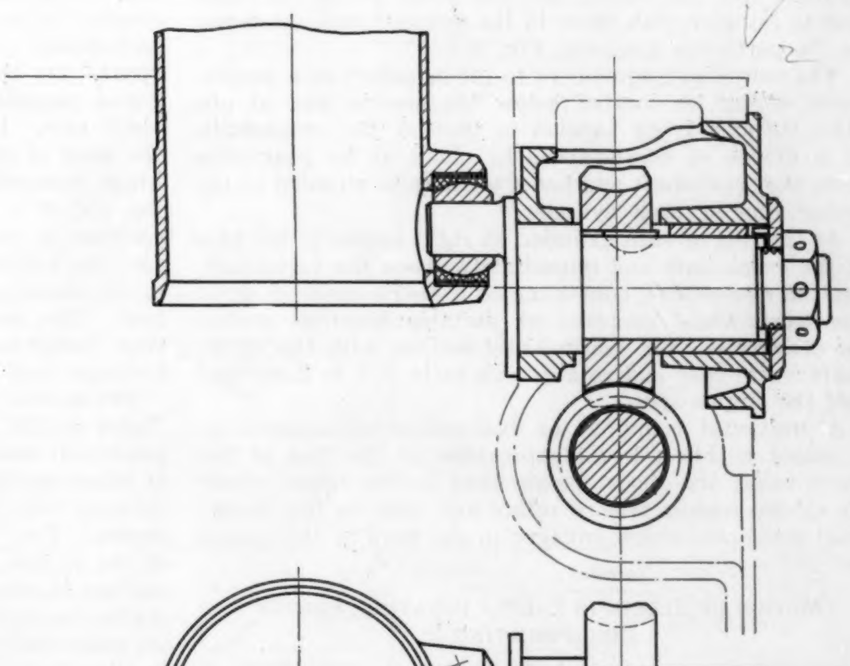


FIG. 8—SLEEVE-DRIVING MECHANISM AT PRESENT IN USE

This Is a Modification of the Original Type Shown in Fig. 5 and Has Given Entire Satisfaction. The Adoption of a Universal Ball-and-Socket Connection Has Many Advantages; It Is Lighter, Occupies Less Space, Allows for Any Inaccuracies in the Alignment of Parts, and Has a Smaller Sleeveshaft Stroke for a Given Area of Port Opening

An interesting side-light on the patent situation was the action for infringement brought against Argylls, Ltd., by Knight & Kilbourne in November, 1911. The case was tried in July, 1912, and resulted in judgment for the defendants. An appeal held in February, 1913, also was in favor of Argylls, Ltd. It should be pointed out, however, that the Knight construction, patented in 1905, under which the suit was brought, was not the double-sleeve type, but a cylinder acting as a single sleeve-valve, having interrupted reciprocatory motion without oscillation.

Mechanical Description

Referring to the cross-sectional arrangement shown in Fig. 3, it will be seen that the crankshaft, connecting-rod and piston are of conventional design and not necessarily different from those used in a poppet-valve type of engine. The essential difference lies in the substituting of a single valve of cylindrical form for the usual poppet-valves.

The cylinder is open-ended and has port-openings cut on its circumference immediately below the bottom edge of the cylinder-head or stationary piston. Intake and exhaust-ports are on opposite sides of the cylinder-block so that separate manifolds are employed.

The water-jacket surrounding the cylinders is free from pockets and tortuous passages, and provides access for inspection to the water-cores between the exhaust-ports through openings on the top face of the cylinder. A water-header casting encloses the top of the water-jacket, the necessary water-joint being made by securing the header to the cylinder by ring-nuts on the cylinder-head. Over the water-header is placed a stamped cover that acts as an ignition-wire carrier and serves to enhance the appearance of the engine.

The tubular sleeve-valve is interposed between the cylinder and the piston, and has ports cut at its upper end to register with those in the cylinder-wall, as shown in the port-cycle diagram, Fig. 4.

The valveshaft, equivalent to the camshaft of a poppet-valve engine, is located below the sleeves and at one side, its axis lying parallel to that of the crankshaft. It is driven at engine-speed by chain or by gear-train from the crankshaft and has a worm-gear situated at the center line of each cylinder.

At the foot of each cylinder, at right angles to the axis of the crankshaft and immediately above the valveshaft, lies the sleeveshaft, consisting of a single cranked shaft and worm-wheel mounted on suitable bearings within the crankcase. The worm-wheel meshes with the valve-shaft worm-gear and rotates at a ratio of 1 to 2, or one-half the engine-speed.

A universal coupling, or ball-and-socket connection, is placed within a housing provided at the foot of the sleeve-valve, the socket being fixed to the sleeve, while the sphere zone is free to rotate and slide on the sleeve-shaft crankpin, which engages in the bore of this member.

Motion of Sleeve Is Partly Rotating, Partly Reciprocating

Rotation of the sleeveshaft imparts to the sleeve a partly rotating and partly reciprocating motion. Any point on the sleeve surface travels in a closed curved path elliptical in shape. The path of travel of the sleeve-shaft crank and the universal coupling at the point of actuation is circular, but, when projected on to the sleeve-wall, becomes elliptical, owing to the radius of the sleeve surface being less than the distance from the axis of the cylinder to the point of actuation, and the fact that the sleeve oscillates around the cylinder axis. The general appearance of a typical engine may be seen from the inlet and exhaust-side views.

The port-cycle diagram, Fig. 4, shows one complete cycle of sleeve movement, the relative positions of the piston being indicated diagramatically at the side of the drawing. At the beginning of the intake stroke, the sleeve is at its bottom center, and all ports are closed (upper left view). As the piston descends, the sleeve moves around and up the lower left-hand portion of the travel ellipse, the intake-ports in the sleeve uncovering the intake-ports in the cylinder (central left view). Intake closing occurs when the bottom straight-edge of the sleeve-port coincides with the top straight-edge of the fixed port in the cylinder, lower left view. As the piston turns on the compression stroke, the sleeve continues to travel upward, reaching its top center at the same time as the piston (upper right view). During the power stroke, the sleeve moves over and down the top right-hand portion of the travel ellipse. Exhaust opening takes place when the bottom edge of the sleeve exhaust-port meets the top edge of the port in the cylinder (central right view), the sleeve moving downward as the piston moves upward on the exhaust stroke. In the lower right view, the maximum exhaust-opening occurs, the sleeve traveling on the lower right-hand portion of the ellipse until the flank edges of the ports coincide, closing the ports and completing the cycle.

Sleeve-Driving Mechanism

The design of the mechanism for actuating the sleeve is an interesting problem and many schemes have been tried out from time to time. All things considered, however, the gear type of drive in various forms has proved the most satisfactory. Some of the drives in use are shown in Figs. 5, 6, 7 and 8. In Fig. 5, the original Argyll type is given. This employs skew-gears to transmit the drive from the valveshaft to the sleeve-shaft. On the inner face of the sleeveshaft, a hole is bored parallel to, and at a definite distance from, the shaft axis. Into this hole the actuating-pin is entered, the head of the pin being machined with flats to form a hinge connection with lugs at the base of the sleeve by the aid of a pivot-pin. The actuating-pin is free to oscillate in the sleeveshaft hole and thus to compensate for the variation of distance between the center line of the sleeve and the axis of the hinge-pin during operation. This mechanism works satisfactorily, but is somewhat heavy and costly, owing partly to the use of ball-bearings and ball-thrusts.

The second type, shown in Fig. 6, was used by Picard-Pictet et Cie, of Switzerland. This gives a rigid and practically wearless mechanism, but has the disadvantage of being much too heavy, the placing of the sleeve lugs between the cylinders adding considerable length to the engine. Two valveshafts are employed, one at each side of the engine. These run at one-half the engine-speed and are identical, taking the form of small-throw crankshafts, having a throw for each cylinder. The throws are connected by a cross-link, one end of which is floating, to allow for slight inaccuracies in synchronism. At the center of the link, connection is made with the sleeve by a hinge-joint. It would seem that this type of drive is best suited for large engines of the motorcoach type. The cross-link could be made of duralumin or any other light alloy.

A modification of the type shown in Fig. 6 is illustrated in Fig. 7. This is known as the link-drive and was first

used on the 1919-model Argyll "Mark A" engine. It is lighter and cheaper than the type shown in Fig. 6, but is obviously inferior mechanically. The necessary lengthening of the engine is a disadvantage, as is also the fact that, like that of Fig. 6, the assembling of the driving-mechanism must be done in its position in the crankcase. An advantage that should not be overlooked is the coupling effect of driving each sleeve from a common valve-crankshaft, so that the valve-timing is foolproof.

The present sleeve-driving mechanism is shown in Fig. 8, and is the same as that shown in cross-sectional arrangement in Fig. 3. This, it will be seen, is a modification of the original type of drive shown in Fig. 5. Introduced in 1921 in the "Mark N" engine, it has given entire satisfaction. The adoption of a universal ball-and-socket connection has many advantages; it is lighter, occupies less space, and allows for any inaccuracies in the alignment of parts. The distance from the axis of the cylinder to the center of actuation is less than that of any previous drive, thus giving a smaller sleeveshaft stroke for a given area of port-opening. If the port area of the type shown in Fig. 5 for a given stroke is 1.00 sq. in., the port area of the other types would be 0.85 sq. in. The sleeveshaft and worm-wheel shown in Fig. 8 are built up as a unit in a bearing housing, the outside diameter of which is eccentric to the bore in order to facilitate assembling. The gears run in a constant-level oil-bath.

An interesting drive is incorporated in the new Aster engine. The sleeve is actuated between the cylinders by

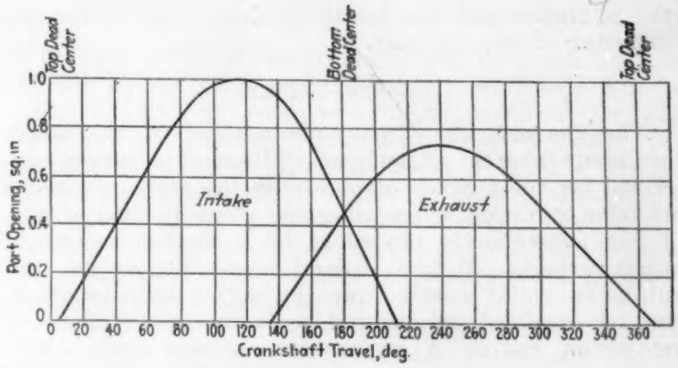


FIG. 10—TYPICAL VALVE-OPENING DIAGRAM
This Shows the Quick Opening and Closing, also the Decided "Dwell"

a small auxiliary crankshaft and a duralumin connecting-rod, the latter being pivoted at its center within a sliding cross-head, the connection to the sleeve being made with the conventional ball-and-socket joint. The travel of the sleeve surface is approximately D-shaped instead of elliptical.

Aside from the fundamental considerations of design, the requirements of a mechanism for imparting an elliptical motion to the sleeve are that it must be free from awkward assembling operations, such as connecting parts together in a position inside the crankcase, the sleeves should be similar, the center distance from the axis of the cylinder to the point of actuation must be kept at

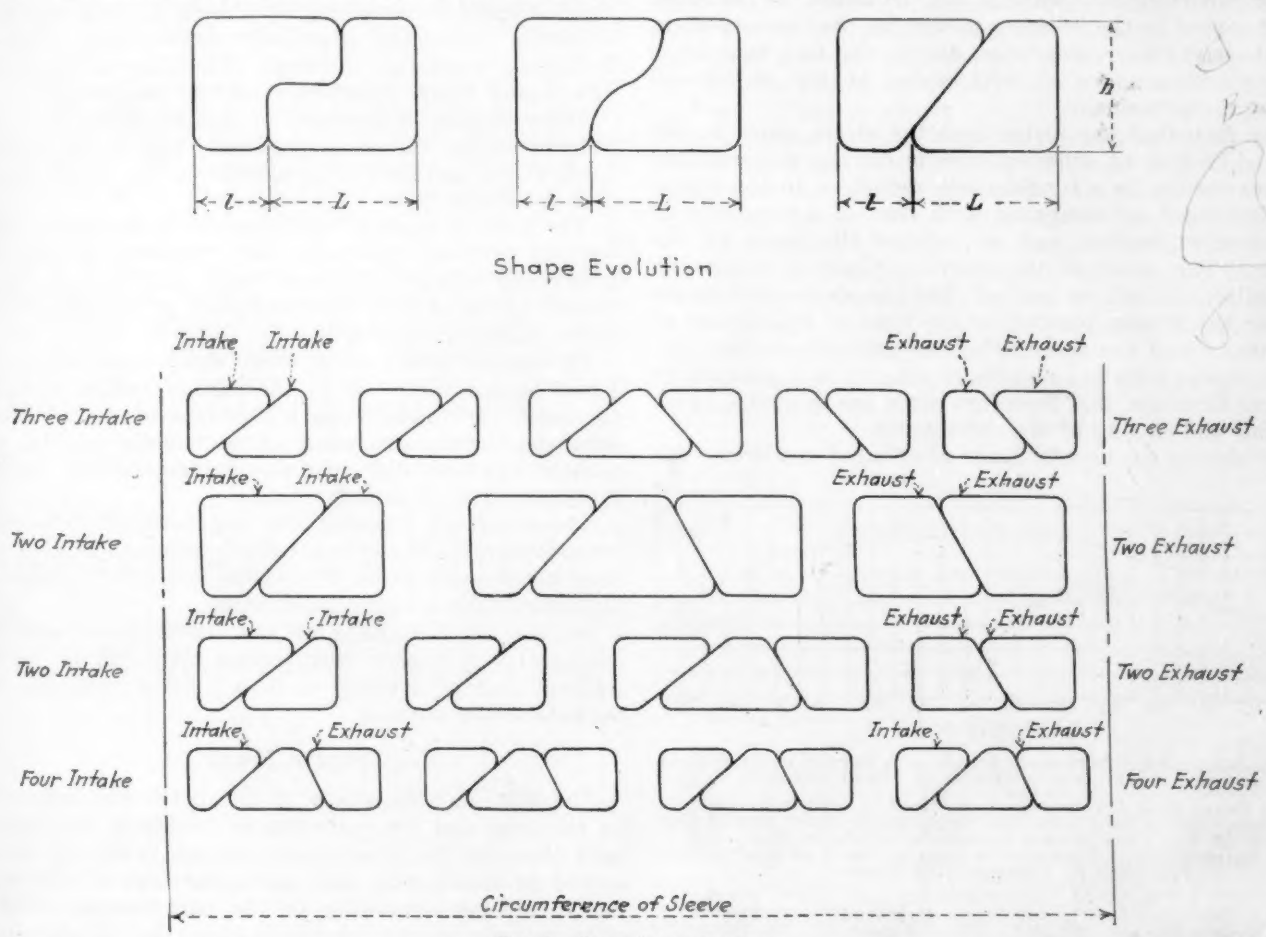


FIG. 9—PORT ARRANGEMENTS
Maximum Area with Maximum Travel Is Obtained by Using a Port Shaped Like That Shown in the Drawing at the Left of the Upper Row, but, Apart from Difficulties in Machining, Such a Shape Is Impracticable Owing to Interference between the Sleeve and the Cylinder-Ports on the Downward Stroke of the Sleeve. This Interference Is Overcome by Rounding Off the Corners of All Ports, as Shown in the Central View. To Simplify the Machining of the Port-Cutting Cam, It Is Usual To Modify the Port Outline To Give Straight Edges, as Shown at the Right End of the Upper Row. Some Possible Arrangements for Various Numbers of Intake and Exhaust-Ports Are Shown in the Lower Part

the minimum and the length of drive kept within the diameter of the cylinder.

Sleeve Valves

The characteristic twisting-movement of the sleeve has many inherent advantages. Although primarily conceived for the purpose of obtaining the proper sequence of valve operation, when using one sleeve instead of two, it has subsequently proved to be a decided benefit in other respects. It is a natural lubricating-motion, the oil being rolled evenly over the entire sleeve-surface, and not localized and sheared, as in the case of a sleeve or piston having a reciprocating-motion only. Oil-grooves are not necessary on the surface of a single-sleeve valve.

The movement of the sleeve approaches harmonic motion, and does not call for the sudden reversal of the direction of travel with its attendant inertia-loading, as does a sleeve with purely reciprocating motion.

Again, the twist dissipates the heat lost to the sleeve-wall over a larger area, giving more even temperatures and therefore reducing the distortion to the minimum. During the compression and power strokes, when the sleeve is subjected to the greatest pressure, it is moving with the piston, and the sleeve-ports are protected between the water-cooled surfaces of the cylinder and the cylinder-head.

It has not been found necessary to fit a sealing-ring to the cylinder-head, such as that used in the double-sleeve-valve engine. This is due, no doubt, to the baffle effect caused by the twisting-movement that smoothes out minute surface-irregularities, and to the fact that there is a sealing-surface at both sides of the sleeve-wall during compression.

The fact that the piston and the sleeve move in the same direction at different speeds during the pressure strokes results in a considerable reduction in the piston rubbing-speed, as compared with that of a conventional poppet-valve engine, and so reduces the wear of the piston. The wear of the sleeve surface is practically negligible. It will be noticed that the sleeveshaft crank is near the 90-deg. position at the time of the closing of the intake and the opening of the exhaust, so that the sleeve moves with the maximum velocity in a practically vertical direction, and therefore gives the desirable quick opening and closing of the valve-ports.

The sleeves are usually made of cylinder cast-iron, cast

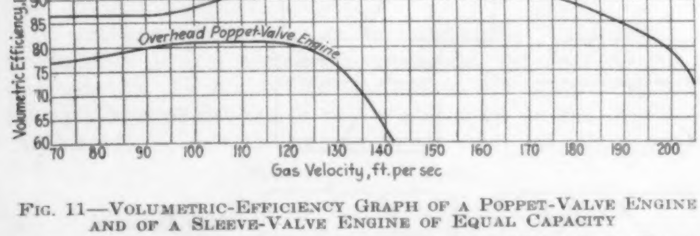


Fig. 11—Volumetric-Efficiency Graph of a Poppet-Valve Engine and of a Sleeve-Valve Engine of Equal Capacity

This Is Taken from a Paper by E. B. Wood in Which It Is Shown That, under Equal Conditions, the Single-Sleeve-Valve Engine Has at Least 20 Per Cent Better Volumetric Efficiency Than Has a Poppet-Valve Engine. Comparative Data on the Two Engines Are Presented in Accompanying Table

Type of Engine	Overhead Poppet	Single Sleeve-Valve
Bore, in.	2.4800	2.7560
Stroke, in.	4.7200	3.5600
Capacity, cu. in.	22.8000	22.2900
Normal Compression-Ratio	4.7000	4.0000
Effective Compression-Ratio	3.9500	3.5500
Specific Inlet Area, sq. in. per cu. in.	0.0557	0.0457
Inlet Valves Closes Late, deg.	52.0000	35.0000

in a rotating mold, although ordinary sand-castings are entirely satisfactory, if carefully made. The thickness of the wall of the sleeve is governed by what the machine-shop can handle without fear of breakage. This will be found ample for strength under working conditions. In practice, the thickness of the wall ranges from 5/64 in. for the $2\frac{3}{4}$-in. bore to 9/64 in. for the 5-in. bore.

Steel sleeves are sometimes used when high engine-speed is desired. It is usual to manufacture them from seamless steel-tubing, the boss for actuating being formed by extruding operations. A sleeve of average diameter is fitted to the cylinder-bore with a tight 0.003-in. and a slack 0.002-in. feeler.

The ball-and-socket connection has evolved from a self-aligning ball-bearing to the present sphere-zone, having a pressure die-cast babbitt-socket cast in position. It has been found that the fit of the ball in the socket can be varied by the pressure applied. The diameter of the sphere-zone is generally made 0.35 D, while the sleeve-shaft crankpin approximates 0.19 D, where D equals the outside diameter of the sleeve. Originally, the ball and the socket were made detachable, but this reduced the bearing area due to flats milled on the ball to allow assembling.

The Cylinder-Head

A detachable head for each cylinder has the advantage of obviating the use of a large casting and gasket. Any cylinder may be examined without disturbing the joints of the others. Explosion balance is assured, as the combustion space is completely machined, and the spark-plug is ideally placed and effectively water-cooled. Cast iron is usually employed, although aluminum is satisfactory and is used where lightness is of first importance.

Many shapes of combustion-chamber have been tried, but, although the hemispherical type is theoretically ideal, it has not proved in practice to be as good as the cone-frustrum type.

The head is made a light push-fit in the sleeve and is secured by four cap-screws, an extra-thin gasket being interposed between the head-flange and the cylinder. It should be noted that the head-joint is not subjected to direct explosion-pressures.

In common with that of other sleeve-valve engines, its power-output improves as the carbon builds up around the head. A standard spark-plug is used; the long-reach spark-plug and extension, characteristic of the early models, has been discarded due to adoption of the cone-frustrum type of cylinder-head.

Trouble from freezing has not been experienced in connection with the cylinder-head, although at first sight this would seem to be a probable source of trouble. A siphoning-tube is sometimes fitted.

Because of the shape of the combustion-chamber, a comparatively higher compression-ratio can be adopted without fear of detonation, 5 to 1 being generally used on automotive engines.

Sleeve Ports

The size and the shape of the ports are determined by the area and the valve-timing required. In common with those of the poppet-valve engine, these can only be settled by experience, each particular type of engine being considered according to the performance required of it.

Maximum area with minimum travel is obtained by using a port shaped like that shown at the upper left corner of Fig. 9, but, apart from difficulties in machining, such a shape is impracticable owing to interference

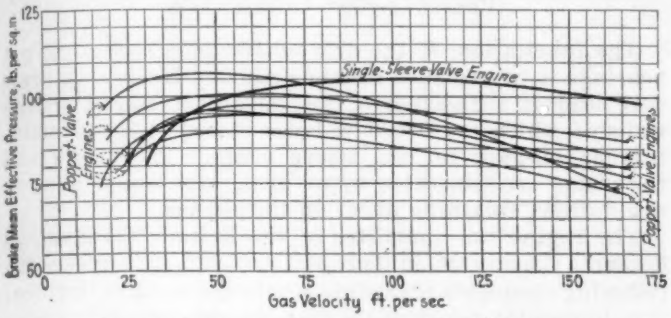


FIG. 12—CURVES SHOWING COMPARATIVE GAS-VELOCITIES OF THE POPPET-VALVE AND THE SINGLE-SLEEVE-VALVE ENGINE

In a Single-Sleeve-Valve Engine, the Brake Mean Effective Pressure Does Not Fall Off Until a Gas Velocity of 110 Ft. per Sec. Has Been Reached, Whereas, in a Poppet-Valve Engine, the Falling Off Takes Place at Approximately 60 Ft. per Sec.

between the sleeve and the cylinder ports on the downward stroke of the sleeve. This interference is overcome by rounding off the corners of all the ports, as indicated by central drawing in the upper part. To simplify the machining of the port-cutting cam, it is usual to modify the port outline to give straight edges, as shown at the upper right corner. This slightly reduces the area for a given sleeveshaft stroke, but results in better machining. The radius at the corner of the port is usually made 1/8 in., this being considered as small as is possible consistently with the up-keep of the cutter. The back edge of the port need not be vertical, but may be curved to conform to the path of travel.

The number of ports incorporated in the design of engines of different types ranges from two intake and two exhaust to four intake and four exhaust. Some of the possible arrangements are also shown in Fig. 9. For a given area, the smaller the number of ports, the greater will be the degree of filling, but the fewer the ports, the greater will be the sleeveshaft throw required; so, as in the case of many other engineering conditions, a compromise must be made. Three intake and two exhaust-ports have been found to be the best all-round combination for automobile engines. This arrangement gives a sleeveshaft throw of moderate dimension and practicable water-cores between the ports in the cylinder, while the maximum port-opening area obtainable compares favorably with good poppet-valve practice, a condition that has proved satisfactory for average engines.

[2] See *Proceedings of the Institution of Automobile Engineers*, vol. 17, part 2, p. 289.

THE DOUBLE-PURPOSE PORT

In each of the port settings, it will be noted that one of the sleeve ports acts alternately as intake and as exhaust. This is known as a "double-purpose" port and is really the joining together of adjacent intake and exhaust-ports. Its inclusion serves to give a greater valve-area, as full use is made of the circumference of the sleeve. In the case of a single-cylinder engine, it is possible to make every port in the sleeve of the "double-purpose" type. This results in the maximum port-area but complicates manifolding.

A typical valve-opening diagram is shown in Fig. 10. This shows the quick opening and closing, also the decided "dwell." A sleeve-valve port will admit more air in a given time than will that of a poppet-valve of equal area, because of the lower temperature of the intake charge and the reduction in restriction and friction; this is one of the reasons that equal areas are sufficient in ordinary practice. This fact is borne out in the volumetric-efficiency tests contained in a paper, Sleeve Valve Engines, by E. B. Wood[2], in which it is shown that, under equal conditions, the single-sleeve-valve engine has at least 20-per cent better volumetric-efficiency than has a poppet-valve engine. The tests were made with a straight-through carbureter without external heat. Mr. Wood's volumetric-efficiency graph of a poppet-valve engine and of a single-sleeve-valve engine of equal capacity is reproduced in Fig. 11.

Another point to be noted is the fact that, in a single-sleeve-valve engine, the brake mean effective pressure does not fall off until a gas velocity of 110 ft. per sec. has been reached, whereas, in the case of a poppet-valve engine, the falling off takes place at approximately 60 ft. per sec. This is shown graphically in Fig. 12, where several modern poppet-valve engines are plotted against the latest single-valve engine. Figs. 11 and 12 make it clear that the intake system of a single-sleeve-valve engine must be considered somewhat differently from that of a poppet-valve engine. In common with poppet-valve engines, the timing of the sleeve valve varies according to the requirements of the engine, but, unlike the poppet, it is constant irrespective of the speed at which the engine may be running.

The average single-sleeve-valve-engine timing-practice is shown in Table 1.

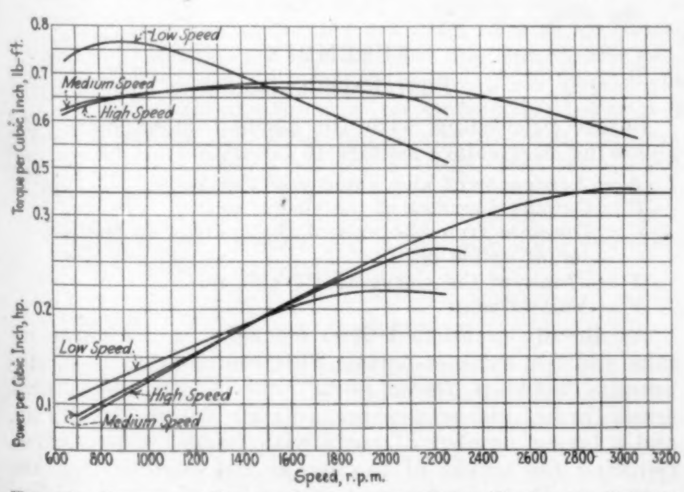


FIG. 13—CURVES OF POWER OUTPUT AND VALVE-TIMING OF SINGLE-SLEEVE VALVE ENGINES

The Data from Which These Curves Are Derived Is Given in Table 1. The Engines from Which the Curves Were Taken Differed in Some Respects, So That an Absolutely True Comparison of the Effect of Timing Only Is Not Presented

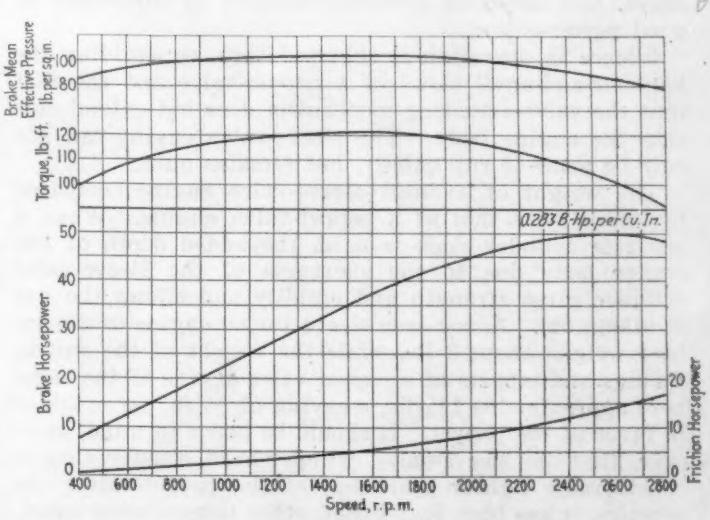


FIG. 14—POWER-OUTPUT CURVE OF SINGLE-SLEEVE-VALVE ENGINE TAKEN AFTER 1000-HR. RUN

The Test of a Six-Cylinder 2 7/8 x 4 3/4-In. Engine Was Made under Full Load at 2000 R.P.M. During the First 100 Hr., the Power-Output Gradually Built Up to 44 B.Hp. After Which It Remained Constant until the Completion of the Test

TABLE 1—AVERAGE TIMING-PRACTICE OF SINGLE-SLEEVE-VALVE ENGINES

Type of Engine	Intake Opens	Intake Closes	Exhaust Opens	Exhaust Closes
Low-Speed	10 Deg. Late	15 Deg. Late	45 Deg. Early	10 Deg. Late
Medium-Speed	10 Deg. Late	20 Deg. Late	45 Deg. Early	10 Deg. Late
High-Speed	5 Deg. Late	30 Deg. Late	60 Deg. Early	15 Deg. Late
Timing Tolerances Allowed on Production	2 Deg. Early to 5 Deg. Late	4 Deg. Early to 4 Deg. Late	4 Deg. Early to 4 Deg. Late	5 Deg. Early to 2 Deg. Late

Fig. 13 shows the power-output per cubic inch of three engines having valve-timing as given in Table 1. The engines from which the curves were taken differed in some respects, so that an absolutely true comparison of the effect of timing only is not presented.

Advantages of the Single-Sleeve-Valve Engine

The chief advantages of a single-sleeve-valve engine are: (*a*) sustained operating-efficiency, (*b*) good power-output, and (*c*) silence in operation. A 1000-hr. test-run under full load at 2000 r.p.m. was recently made on a six-cylinder $2\frac{7}{8}$ x $4\frac{1}{4}$-in. engine. During the first 100 hr., the power-output gradually built up to 44 b.hp., after which it remained constant until the completion of the test. Measurement of sleeve driving-gear back-lash was made by an extended arm attached to the sleeveshaft and, although a maximum increase of 0.017 in. on the pitch-line was recorded, the gears ran as quietly as at the beginning of the test. On dismantling the engine, the maximum wear on the piston skirt was found to be 0.001 in., while the wear on the outside diameter of the sleeve was undiscernible. Fig. 14 shows a power-output curve taken from this engine after the 1000-hr. run.

The adoption of a sleeve valve obviates such things as the "grinding-in" of valves, the ingress of unwanted air through worn valve-guides, the distortion or sticking of the valve, the adjustment of clearance, the breakage of valve-springs, and frequent decarbonization.

The rapid opening of the ports, the type of port-opening obtained, positive timing, unobstructed intake-passages, and increased compression-ratio all contribute to good power-output.

Silence in operation is achieved through avoiding the hammer-and-anvil blows of a poppet-valve and the fact that the valve-actuating mechanism does not extend outside the engine body. The sleeve-valve engine can not only be made to run quietly, but remains quiet.

The weight of a single-sleeve-valve engine compares favorably with that of a poppet-valve engine. When a separate cylinder-block is used, the added depth of the engine body due to the shortness of the sleeve-valve cylinder gives strength and rigidity and allows the use of aluminum. A cast-iron sleeve for an engine of $2\frac{3}{4}$-in. bore weighs about 2 lb., while the weight of the valves, springs and tappets of a poppet-valve engine of the same bore approximates $1\frac{1}{4}$ lb., a saving of $\frac{3}{4}$ lb. per cylinder in favor of the poppet. It should be borne in mind, however, that the sleeve-valve cylinder-head construction is considerably lighter than that of the poppet-valve. In practice, it has been found that, other things being equal, a single-sleeve-valve engine of average bore, with an aluminum casing, is about 50 lb. lighter than a poppet-valve engine of conventional cast-iron construction.

Pressure-Feed Lubrication

The lubrication of the crankshaft and connecting-rod bearings is by pressure feed of orthodox design. A pressure lead is connected to the valveshaft tunnel in the walls of which are overflow holes placed so as to maintain an oil-bath for the sleeve gears. The sleeve and the piston are lubricated by oil mist, care being taken to avoid direct splashing of oil on the sleeves.

The engine sub-committee of the British Aeronautical Research Committee, in its report for 1925-1926, makes the following comments regarding single-sleeve-valve engines:

> During the course of the year the sub-committee has given considerable attention to the results that have been obtained in the development of single-sleeve-valve engines, of the Burt-McCollum type. It is of the opinion that these engines offer definite advantages for use in aircraft. It has been proved without any doubt that the absence of hot exhaust-valves diminishes the tendency to detonation and, in consequence, allows a sleeve-valve engine to be used at a higher compression-ratio than a poppet-valve engine of corresponding size. The increase in efficiency so obtained is important. It also appears that the weight of a complete engine is not likely to be substantially increased by the substitution of single sleeve-valves for poppet-valve. The sub-committee considers that the research work has now reached such a stage that the development of multi-cylinder aircraft-engines using sleeve valves should be encouraged.

In a supplement to the above report the following appears:

> For some time past, work has been in progress on the evolution of a sleeve-valve engine suitable for aircraft purposes. In a recent report on the present position H. R. Ricardo stated that as the result of from 9 months' to $2\frac{1}{2}$ years' running-experience on several engines the conclusion has been reached that the single-sleeve-valve engine gives better performance than a poppet-valve engine of the same size, maintains its performance far longer and possesses very considerable mechanical advantages.
>
> The sub-committee has examined in detail the results of all tests undertaken and considers that the potential value of the single-sleeve-valve engine for aircraft purposes has been fully demonstrated. In particular, experience has shown that it is possible to keep the sleeve fully lubricated without excessive oil-consumption, and that the absence of hot exhaust-valves in a sleeve-valve engine reduces the tendency to detonation of the fuel, and therefore allows the use of higher compression-ratios than a poppet-valve engine of similar size.

APPENDIX

Port Calculation

Before proceeding with the calculation of ports, the following particulars require to be settled:

A = Arrangement and number of the ports
B = Outside diameter of the sleeve, in.
C = Distance from the axis of the cylinder to the center of actuation, in.
T = Throw of the sleeveshaft crank, in.
V = Valve-timing

As already mentioned, it is desirable to use three intake and two exhaust-ports. This combination is a compromise between fewer ports with larger sleeveshaft crank-throw, giving greater over-all height of engine, and a larger number of ports with smaller crank-throw, reducing the height of the engine but complicating the coring in the cylinder and increasing the port-cutting time. Reference should be made to the inlet-port-opening chart, Fig. 15, from which the maximum-opening

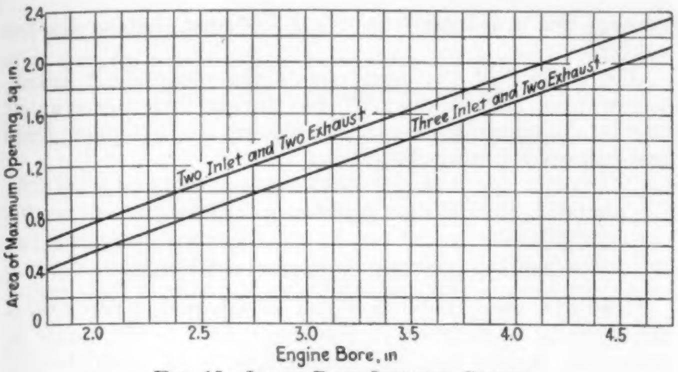


FIG. 15—INLET PORT-OPENING CHART
From This the Maximum-Opening Area in Square Inches for Different Arrangements of the Port-Settings May Be Seen

area in square inches for different arrangements of port-settings may be seen. If three intake and two exhaust-ports do not give sufficient area for a particular engine, taking a poppet-valve as a basis, two intake and two exhaust-ports should be adopted.

The outside diameter of sleeve D is obviously determined by the bore of the engine and the thickness of the sleeve-wall.

Using the ball-and-socket type of coupling, the distance from the axis of the cylinder to the center line of the ball, to the nearest even dimension, is

$$C = 0.625\ D \qquad (1)$$

THE SLEEVESHAFT CRANK-THROW

The sleeveshaft crank-throw T is determined by the outside diameter of the sleeve, the center distance C, and the port arrangement A, given as the total number of ports per cylinder. The stroke of the sleeveshaft crank is approximately equal to the width of the port and the space between the ports, so that, if the circumference of the outside diameter of the sleeve be divided by twice the number of ports minus 1 (there being one less space than ports), the approximate stroke of the sleeve will be $\pi D/(2A - 1)$. The distance from the sleeve-wall to the axis of the cylinder is different from that of the point of actuation to the axis of the cylinder; therefore an allowance must be made in calculating the crank-throw T.

$$T = (\pi D \times 0.625D)/[(2A - 1) \times 0.5D \times 2] = 1.96D/(2A - 1) \qquad (2)$$

or

$T = 0.218D$ for three intake and two exhaust-ports (3)

and

$= 0.280D$ for two intake and two exhaust-ports (4)

Taking an engine having a $2\tfrac{3}{4}$-in. bore as an example of the passenger-car type for port calculation, the necessary particulars are first determined. A poppet-valve engine of the same bore and of conventional design has a maximum intake-valve diameter of one-half the engine bore, so that, with a seating 1/16 in. deep the diameter of the port is

$$(0.5 \times 2.75) - 0.125 = 1.25 \text{ in.}$$

Assuming a valve-lift of $\tfrac{1}{4}$ in., the maximum valve-opening area is approximately

$$1.25 \times \pi \times 0.25 = 0.98 \text{ sq. in.}$$

PORT ARRANGEMENT

Referring to the port-opening chart, Fig. 15, it will be seen that, for $2\tfrac{3}{4}$-in. bore, a port arrangement of three intake and two exhaust-ports gives a valve area equal to that of a poppet-valve; therefore, this setting will provide ample valve-area for the type of engine under consideration.

A = Three intake and two exhaust-ports
D = Bore + twice the sleeve thickness
$= 2.75 + 0.15625$
$= 2.906$-in. diameter
$C = 0.625\ D$
$= 0.625 \times 2.9$
$= 1.8125$ in.
$T = 0.218\ D$
$= 0.218 \times 2.9$
$= 0.632$, say, 0.625 in.
V = the valve timing. Assume that the intake-opening is 5 deg. late; the closing, 32 deg. late; the exhaust-opening, 44 deg. early; the closing, 10 deg. late.

Referring to the port calculation diagram, Fig. 16, the sine of one-half the angular travel of the sleeve equals the sleeveshaft throw divided by the center distance between the sleeve axis and the point of actuation:

$$\alpha/2 = 1/2 \text{ angular travel} = T/C \qquad (5)$$
$$= 0.6250/1.8125$$
$$= 0.3448$$
$$= 20 \text{ deg. } 10 \text{ min.}$$

therefore

$$\alpha = \text{Angular travel}$$
$$= 20 \text{ deg. } 10 \text{ min.} \times 2$$
$$= 40 \text{ deg. } 20 \text{ min.}$$

HORIZONTAL TRAVEL OR LATERAL MOVEMENT OF SLEEVE

The horizontal travel or lateral movement of the sleeve measured on the outer surface of the sleeve-wall must next be found.

$$H = \text{Horizontal travel} = \alpha\pi D/360 \qquad (6)$$
$$= \alpha \times D \times 0.00872$$
$$= 40.33 \text{ deg.} \times 2.9 \times 0.00872$$
$$= 1.0229 \text{ in.}$$

The length of the port is obtained by subtracting an allowance for seal from the horizontal travel. This seal, or cover, as it is called, is necessary in order to prevent pressure leakage during the passage of a sleeve-port between adjacent ports in cylinders. The amount of cover may be varied in order to bring the port length to an even dimension, but should never be less than 0.05 in.

The length of the port equals

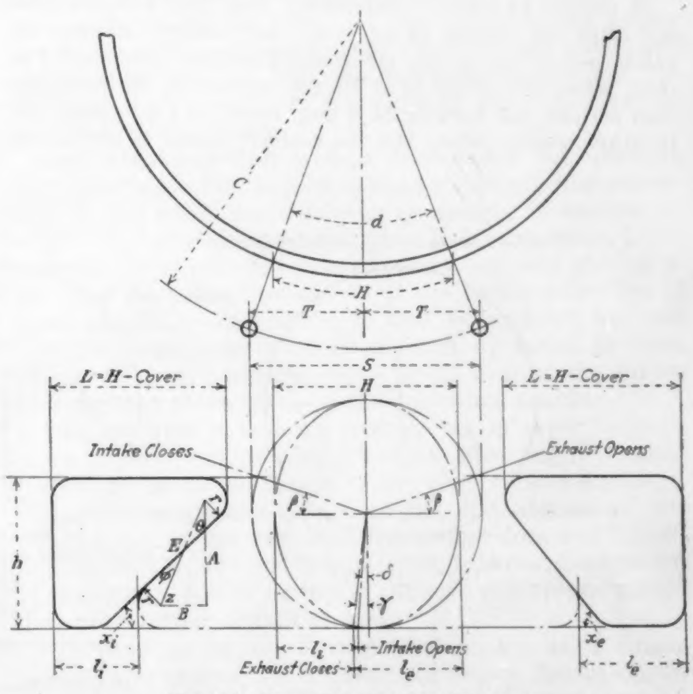


FIG. 16—PORT-CALCULATION DIAGRAM
The Sine of One-Half the Angular Travel of the Sleeve Equals the Sleeveshaft Throw Divided by the Center Distance between the Sleeve Axis and the Point of Actuation

$$L = H - \text{cover} \quad (7)$$
$$= 1.0029 - 0.0529$$
$$= 0.97 \text{ in.}$$

Next, the width of the large spaces between the ports is found by adding a variable cover-allowance to the horizontal travel, so that a space equals

$$W = H + \text{cover} \quad (8)$$
$$= 1.0229 + 0.0501$$
$$= 1.073 \text{ in.}$$

Having the length of the port and the width of the large space, the spacing of the ports around the circumference of the cylinder can now be settled. In the three intake and two exhaust-port arrangement under consideration, these are

5 ports at 0.970 in. =	4.850 in.	
3 spaces at 1.073 in. =	3.219 in.	
Total	8.069 in.	

so that this figure subtracted from the circumference of the outside diameter of the sleeve gives the sum of the two remaining small spaces.

Therefore, a small space equals

$$0.5\,(\pi D - 8.069) = 0.5\,(9.1302 - 8.069)$$
$$= 0.5 \times 1.0612$$
$$= 0.5306 \text{ in.} \quad (9)$$

Height of Ports

The height of the ports is controlled by the throw of the sleeveshaft and the valve-timing at the intake-closing and the exhaust-opening positions. In Fig. 17, three timing-diagrams are given, that at the left being the crankshaft or flywheel timing; the central one, the same timing transferred to the one-half engine-speed sleeveshaft; and that at the right, simply the central diagram with the datum points moved round, or advanced so as to bring the points of intake-closing and exhaust-opening a uniform distance from the horizontal center-line, the timing periods remaining unchanged. The advance, or the angular distance through which the sleeveshaft crank is moved ahead of the crankshaft, equals $(X - Y)/2$ deg. on the sleeveshaft. This, for the example taken, is $(22 - 16)/2 = 3$ deg.

It should be clearly understood that this advance does not alter the timing in any way, but simply changes the relative position of the sleeveshaft to the crankshaft; so that, when the latter is at its top center on the compression stroke, the former is 3 deg. over its top center; or, in other words, when the sleeveshaft crank is on its top center, the crankshaft is $3 \times 2 = 6$ deg. before its top center.

The height of the port equals the sleeveshaft crank-throw plus the product of the throw and the sine of the intake-opening or exhaust-closing angle, taken from the balanced timing-diagram.

$$h = T + (T \sin \beta) \quad (10)$$
$$= 0.625 + (0.625 \times \sin 19 \text{ deg.})$$
$$= 0.8284 \text{ in.}$$

Advancing the Sleeveshaft Crank

It will be seen that the object of advancing the sleeveshaft crank in relation to the crankshaft is primarily to make the intake and the exhaust-ports of equal height and, consequently, to simplify the port-cutting operation. There is, however, another advantage that should not be overlooked. The height of the cylindrical portion of the combustion-space is governed by the height of the port, that is, the top of the piston at top center coincides with the lower edge of the cylinder ports, while the foot of the cylinder-head is placed about 1/32 in. above the top edge of the ports. A reduction in the port height, due to balancing, allows a reduction in the height of the cylindrical portion, with a corresponding increase in the height of the recess in the cylinder-head. This tends to promote better turbulence of the gas, and at the same time raises the spark-plug out of the deep pocket, a characteristic of early-model engines, on which the intake and the exhaust-ports were of different heights, calculated directly from an unbalanced timing-diagram.

The port-flank angles, which govern the opening of the intake and the closing of the exhaust, are next determined. To obtain these, the dimensions l_i and l_e, shown in Fig. 16, are first solved.

$$\text{Intake-port tail} = l_i = 0.5H - [(T \sin \delta\ (0.5D/C)] \quad (11)$$
$$= 0.5 \times 1.0229 - (0.625 \times \sin 5\tfrac{1}{2} \text{ deg.} \times 0.8017)$$
$$= 0.4634 \text{ in.}$$

$$\text{Exhaust-port tail} = l_e = 0.5H + (T \sin\gamma \sqrt{0.5D/C}) \quad (12)$$
$$= 0.5 \times 1.0229 + (0.625 \times \sin 8 \text{ deg.} \times 0.8017)$$
$$= 0.5812 \text{ in.}$$

Solution of flank angles is as follows:

$$A = h - 2r$$
$$B = L - (l_i \text{ or } l_e - 2r)$$
$$\text{Tan}\,\theta = B/A$$
$$E = B/\sin\theta$$
$$\text{Sin}\,\varphi = r/0.5E$$
$$Z = 90 \text{ deg.} - \theta$$
$$X = Z - \varphi$$

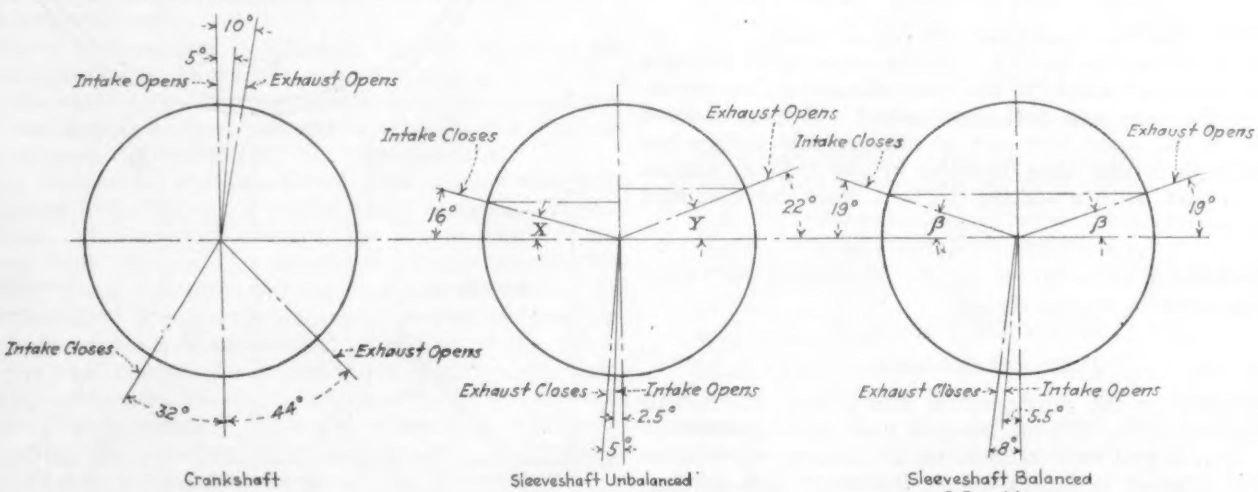


Fig. 17—Timing Diagrams

The Diagram at the Left Is the Crankshaft or Flywheel-Timing; the Central Diagram, the Same Timing Transferred to the One-Half Engine-Speed Crankshaft; That at the Right Is Simply the Central Diagram with the Datum Points Moved Round, or Advanced So as To Bring the Points of Intake Closing and Exhaust Opening a Uniform Distance from the Horizontal Center-Line, the Timing Periods Remaining Unchanged

For the example taken, the flank angle X is 42 deg. 47 min. for the intake; 51 deg. 38 min. for the exhaust.

The Port-Opening Diagram

Having all the port dimensions, it is a simple matter to construct a port-opening diagram. Adjacent intake and exhaust-ports on the cylinder, and the sleeve-travel ellipse are drawn on an enlarged scale, say 10 times the full size, the sleeve-travel ellipse being constructed geometrically from the sleeveshaft stroke and the horizontal travel, using 10-deg. divisions for convenience. Sleeve-timing marks should be clearly indicated. Next, the sleeve ports, one intake and one exhaust, are drawn on a separate piece of tracing-paper and placed over the cylinder-port drawing, so that the ports will be in line, with the intake-port flanks coincident. In this position, a mark is placed over the travel ellipse at the point of intake opening. Keeping the ports horizontal, the mark is moved round the travel ellipse, the area of opening being measured by a planimeter at every 10 deg. of travel. After making correction for the enlarged scale and the actual number of ports, the readings are plotted against the crankshaft travel, to give a port-opening diagram.

THE DISCUSSION

H. M. Crane[3]:—When I first saw the notice of this meeting, I came to the conclusion that it was to be just another one of "those things," those wakes attending the burial of the poppet-valve engine that have been so successful in the past. Mr. Knight put it away 30 years ago and, at intervals ever since, it has been discovered to be defective in many ways, just like the gear-box, which used to be called a "clash box," was "utterly impossible" and was a device that no engineer would think of using.

I think, however, that the paper has presented the Argyll engine, or the Burt-McCollum single-sleeve engine, as another interesting type of engine, and in this I fully agree.

The history of the Argyll engine brings out one important point that may now be solved, namely, the method of driving the sleeve. It is a far from simple proposition to operate the sleeve in the position in which it requires to be and with sufficient lightness of parts to make reasonably high speed possible. My own experience with straight spiral-gears of the type now proposed has been that such gears are about equal to driving an oil-pump, or other similar device.

It is possible that by the use of special material they will be adequate, but we must bear in mind that straight spiral-gears have practically no bearing-area. A change in the size does not help much but increases the linear speed of the gear and, though the pressures are reduced, the over-all result is not greatly improved.

The fact remains that no type of drive is universally used today with this engine. The Aster car abroad uses a type that is different from the one proposed here; and time alone will show what success is to be obtained.

The other point that is most noticeable in sleeve-valve engines of all types is the fact that they are not strictly gas-tight, especially at slow speeds. If ports are used that are large enough to get a proper valve-opening, the inlet and exhaust-ports are so close together circumferentially that some leakage between them is almost certain to occur, for the vacuum on the manifold often rises to 18 or 20 in. of mercury.

Today we have reached the point of taking power from the inlet-manifold for anything that accessory makers happen to think is desirable to operate.

A friend of mine last summer was operating a foreign car of small size and tried to maneuver it out of a yard. He had to "back and fill" several times. Whenever he put the brake on, the engine stopped. That could be prevented by keeping the throttle fairly well open; but then the brake would not operate; so you could take your choice.

Of course, that engine was extremely small but the fact remains that if really good throttled operation is to be obtained, the inlet and exhaust-valves must be gas-tight. I could not restrain a smile when I read of "unwanted air" leaking through the inlet and exhaust-stems of the poppet-valve engine, when we know what takes place in the ports of the sleeve-valve type, that is, if they are sufficiently large.

Another question, of course, is the necessity for burning out carbon. Frequent burning-out of carbon in a well-designed poppet-valve engine is usually due to carrying a higher compression than is suitable for the district or for the type of service involved. I know of very few poppet-valve engines in which carbon is burned for the sake of getting it out of the engine. It is the result of the owner's thinking that the engine is knocking.

I have been told that one of the early types of sleeve valve, the double, which undoubtedly has somewhat similar characteristics, was put on a test at the Auto Club and operated successfully during a long run. The reason seemed to be that, at the end of the test, the inlet-port was only half open; a wall of carbon had been built up so that the volumetric efficiency fell off to what was needed to keep the engine going properly.

The figures on volumetric efficiency that have been given are probably correct. The direct lead of the ports of a sleeve-valve engine into the cylinder should give a higher volumetric-efficiency than that of the poppet-valve engine, that is, of many L-head engines produced in this Country. In the latter, the ports are full of sharp corners. The bends are so close that no proper stream-lining can take place and the valves themselves frequently open into ports where the edges of the valves barely escape the walls of the cylinder-head, often on the sides and almost invariably on top, the valve rising one-half the distance, and sometimes more, from the valve-seat to the head of the cylinder.

Any laboratory test with a manometer will indicate that it is impossible to pass much air through a construction of this kind; and I have seen designs of engines in which, even if the size of the valve had been reduced, the engines would still have passed more air into the cylinder than the other limitations of the construction would make available. In addition to that, many inlets are tied together, with only a common strip of metal between them, which will account for a great deal of the excess heating that takes place in the incoming charge.

I do not wish to accept a comparison on paper between a sleeve-valve engine and a poppet-valve engine, unless I know all about the design of the poppet-valve engine.

Another point has regard to the straightness of the power-curve or the fact that the torque does not fall off at high speed. It may be due to the inherent advantages in the engine design or to the engine's not producing the low-speed torque that it should.

We have no figures on the performance of a single-sleeve-valve engine, but I have been shown figures on the operation of a double-sleeve-valve engine which was intended to operate at high speed and was designed accordingly. The engine had a compression-ratio of ap-

[3] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

proximately $6\frac{1}{2}$ to 1. That is a compression-ratio which is common in aviation engines only when a good deal of benzol is used in the fuel. This engine showed a maximum mean effective pressure of 130 lb. per sq. in. at any speed, and, at the lowest speed, 700 r.p.m., the mean effective pressure was approximately 110. The best gasoline consumption at any speed was about 0.60, and often 0.70 or 0.75 lb. per hp-hr.

Anyone who has had anything to do with aviation engines realizes what a ridiculous performance that is. First-class aviation poppet-valve engines show mean effective pressures of 135 and 140 and gasoline consumption of less than 0.5 lb. per hp-hr. The only way I can account for this low performance of the sleeve-valve engine is that a heavy leakage occurs at the lower speeds. The power-curve is not concave, but nearly so.

I do not intend to "knock" the sleeve-valve engine, and I do not consider that I am knocking it; but I am simply calling attention to points in which this type of engine is more difficult to handle than the poppet-valve engine. On the other hand, the sleeve-valve engine has distinct advantages in smoothness of operation. The type of combustion-chamber that operates best with the single sleeve-valve and with the Knight engine tends to produce a less noticeable power-impulse for a given mean effective pressure. In other words, the engine, when compared to a great many poppet-valve engines, feels "soft," yet produces equal or better power. That is especially true of engines of the high-turbulence, or what we commonly call the Ricardo, type of head, in which the explosion seems to be extremely rapid and tends to roughness. Those of us who deal with engine tests know what that means, a shuddering feeling, sometimes accompanied by thumping, though frequently not; the engine does not "feel comfortable" when working. That is a worthwhile feature for passenger-car engines and something the public will certainly thoroughly appreciate.

The compression that can be used with sleeve-valve engines is hard to determine. The Knight engine with double sleeves and three oil-films can detonate without the detonation being noticeable to the driver. A set of tests run a few years ago clearly indicated that heavy detonation was caused by the compressions used. The gasoline economy was very bad, much below what should have been obtained, yet observers stated that there was no detonation. The single-sleeve engine undoubtedly should be less affected by detonation, so far as an observer is concerned. The combustion-chamber is extremely favorable, and the absence of a hot exhaust-valve is also favorable.

I hope that, in the near future, Mr. Frederick, or his associates, will be able to tell us more of the actual results obtained and give more details of the engine with which the Argyll type has been compared in making these tests.

A. M. NIVEN[4]:—With regard to Mr. Crane's opening remarks, the fact that our firm manufactures poppet-valve engines is sufficient to indicate that we are not out to "kill" the conventional type of valve. I hope some Knight-engine representative will respond to the criticisms of the double-sleeve engine; criticisms, which, in most cases, do not apply to the single-sleeve engine. Mr. Crane is under the impression that we are using "spiral" gears for driving the sleeves. This is not the case. Full worm-gearing is employed, as is shown in Fig. 3 and in Fig. 8.

Mr. Crane has doubts regarding the high engine-speed obtainable. In this connection, it is interesting to note that, in 1913, when the 15-hp. 160-cu. in. Argyll made the 14-hr. record on the Brooklands track, the average car-speed was 72.59 m.p.h., or about 2400 r.p.m. of the engine, no mean speed at that time for a prolonged run. Today, our automobile engines peak at 3000 r.p.m.

The volumetric-efficiency curves, shown in Fig. 11, were made at the Automobile Engineering Laboratory, Bristol, England, and a full description of the engines and the apparatus used is contained in E. B. Wood's paper[5], Sleeve-Valve Engines.

Volumetric-efficiency tests have not been made at Detroit. It should be borne in mind that the various engines now running at our factory are more or less in the experimental stage with regard to adaptation to American conditions. The torque at low engine-speeds, shown in Fig. 14, compares favorably with that obtainable with poppet-valve engines.

I agree with Mr. Crane's remarks regarding the absence of "roughness" in a sleeve-valve engine compared to that experienced in a poppet-valve engine fitted with a high-turbulence type of head.

One point in connection with carbon: it is a simple matter to decarbonize a single-sleeve-valve engine. We may say that, in Europe, it is not usual for the single-sleeve-valve engine to be decarbonized under 20,000 miles, but, when it becomes necessary, the operation is simple. It is more easily performed, to my mind, than decarbonizing a poppet-valve engine.

E. S. MARKS[6]:—One point that has not been mentioned in the discussion is just what significance the 40,000-mile test had with regard to the wear on the parts. As I recall it, Mr. Frederick has stated that the engine ran for 1000 hr. at 2000 r.p.m. Assuming that that is equivalent to about 40,000 miles, I might state that our experience, in trying to get wear-test figures by running an engine on a testing-block at a given continuous speed, under given steady load, seems to indicate that the results obtained with regard to wear do not mean anything. We have a large number of records of engines that have run from 20,000 to 30,000 miles, or more, where the wear on the parts has been almost insignificant. This is not borne out in service, so we have found it necessary to adopt certain means for accelerating this wear in order to get results on the block. Under what conditions was that wear-test run?

MR. NIVEN:—The test mentioned was not run so much to obtain a measurement of the wear on the piston as of the wear on the actuating-gear. We endeavored to find out whether the wear increased after prolonged running; but the results showed that it did not increase with the time run. In our opinion at the time, 1000 hr. was sufficient, as a test, to discover what we were seeking. The test was not made with the intention of including it in a paper, but purely in connection with our own research work. Had we known at the time that a paper was to be prepared, we probably would have included some other interesting data.

S. W. SPARROW[7]:—Was there any indication of more wear in the producing of grooves on the piston than with the conventional engine? I should think the rings would be given a twisting motion that might possibly increase the wear.

MR. NIVEN:—The question raised by Mr. Sparrow is

[4] M.S.A.E.—Engineer, Continental Motors Corporation, Detroit.

[5] See *Proceedings of the Institution of Automobile Engineers*, vol. 17, part 2, p. 289.

[6] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[7] M.S.A.E.—Engineer, research department, Studebaker Corporation of America, South Bend, Ind.

a popular one often asked regarding sleeve-valve engines. Piston-groove wear has never troubled us in service, and after the recent 1000-hr. test, wear was certainly not noticeable. As a matter of fact, we are using the same pistons and rings in the engine at present on the road.

E. R. HEWITT[8]:—I have been designing poppet-valve engines for many years and have followed the advance in design from the time when engines had a mean effective pressure of about 65 or 70 lb. per sq. in. to the present when we are able to obtain mean effective pressures, with a reasonable amount of compression, as high as 110 lb. We have engines running regularly at 108 lb.

I spent last summer traveling in Europe. During my journey I visited Mr. Ricardo on two occasions, spent the day with him, and inspected the sleeve-valve engine on which the 1000-hr. tests were made. The wear was negligible. As was stated, the engine was in good condition in every way. The part that I look at in our own engine is the timing-gears, to see how much the tooth is worn that comes into contact at the point where the exhaust-valve lifts. That is where the most wear occurs.

In this case I examined the worm-gear to see whether I could find any high spots. In turning it around I found two worn spots on the teeth. I did not know what caused them, but I asked Mr. Ricardo the reason and he said, "You have laid your finger on one of the serious difficulties of this type of engine." These thin sleeves are liable, under certain conditions, to expand under the explosion pressure. Owing to difficulties in lubrication, the gripping may be serious and the cast-iron sleeves sometimes pull the lug off the bottom of the sleeve. Partway down the slope the angular pressure of the piston causes greater pressure on the wall of the sleeve, which is at that time moving fast. That throws an additional load on the gear-teeth at that point and accounts for the two marked places during the revolution of the gear.

No doubt the gearing can be made strong enough to endure. The reason for the adoption of steel sleeves was the fact that the pulling off of lugs of the cast-iron sleeves had occurred, in many cases, due to the gripping at the top.

The last day, I saw one running that was giving a mean effective pressure of 113 lb. per sq. in. I think the bore was $4\frac{5}{8}$ and the stroke $5\frac{1}{2}$ in. It was running on European gasoline. The gasoline in Europe is much better than the gasoline we use in this Country. They do not use cracked material there. The fuel has a larger amount of material of low volatility and has a lower boiling-point.

Mr. Ricardo made a number of tests, shifting from one gasoline to another. The Borneo gasoline carried considerably higher compression, running up as high as 6.0 to 1.0, whereas American gasoline ran about 4.5 to 1.0 before it knocked under the same conditions with a hot piston.

So, any test we get in Europe means nothing as regards the type of fuel we use here. Our engines abroad, Buicks and cars of that type, can run with considerably higher compression than they can here. Some persons even raise the compression a little over there and give the cylinders a more snappy action by taking a cut off the bottom side of the cylinder-head. Their cars do not have the amount of carbon formation that we have. When run on American gasoline, they carbonize less than ours.

I came away with the impression that the sleeve-valve is a good type of engine and that it will come into use and be developed; but I had a marked impression that a great deal of work remained to be done on it to make it commercially correct. The jobs I saw were not manufacturing jobs that could be produced on a large scale under continuous production, and be turned out with the types of labor and of tooling that we must use here. I think the Continental Company will develop a type of engine that is practical and can be made on a production basis. These engines have never been made in Europe as we have to manufacture them here; but I thoroughly believe they will come into use and be developed into a first-class product.

MR. NIVEN:—What was the bore of that engine?

MR. HEWITT:—The engine was $4\frac{5}{8}$ x $5\frac{1}{2}$ in. A small four-cylinder engine, $3\frac{3}{8}$ x $3\frac{1}{2}$ or even $3\frac{3}{4}$ in., gave 50 hp. at 3000 r.p.m. They brazed the steel ring on the bottom to hold the lug and also riveted it on; but neither method was satisfactory.

MR. NIVEN:—Mr. Hewitt has brought out some interesting points in connection with his visit to the Ricardo laboratory. I was unaware that a 1000-hr. test-run had been made at Shoreham. The test mentioned in the paper was made in Detroit with American gasoline, so that Mr. Hewitt's remarks regarding absence of wear are welcome as confirming our findings.

I can assure Mr. Hewitt that the sleeve-driving gear can be made strong enough to endure, and that sleeve breakage is unknown in our automobile engines. Mr. Ricardo's experiments were probably made for aircraft engines, and, naturally, the weight of the sleeve would be lighter than usual.

The 20,000 miles without decarbonization refers to engines running on European gasoline. Poppet-valve engines running on the same fuel will run about 1500 miles without attention in this respect, so that it is logical to expect a proportionate gain when using American gasoline.

The compression-ratio used on the new engines is 5 to 1.

H. D. CHURCH[9]:—A great many automotive engineers who are firm believers in the poppet-valve engine have, for years, been hopefully watching sleeve-valve engine development. The advantages of both double and single-sleeve-valve engines are well known and admitted; and probably, for certain classes of automotive work, this type of engine gives an excellent account of itself. On the other hand, the sleeve-valve type of engine, in its present state of development, is not as suitable for severe heavy-duty service as is the poppet-valve type. For this class of work, there seem to be certain problems inherent in the design. The matter of proper sleeve-lubrication seems to be difficult to handle. Usually, sufficient oil for the maximum loads and speeds seems to result in overoiling, and at light loads in exhaust smoking.

For heavy-duty service in the larger sizes of single-sleeve-valve engine, I think the means of operating the sleeve presents a problem from the standpoint of durability. It is the general impression that, due to the shape of the combustion-chamber and the ports, together with the location of the spark-plug, it is usually possible to run a slightly higher mean effective pressure in a sleeve-valve engine than in a poppet-valve engine of the same dimensions, working to the same detonation values on both engines.

In a hard-working poppet-valve engine, the two hottest members in the combustion-chamber are the centers of the exhaust-valve heads and of the piston-heads; and it is the temperature of these two parts in a poppet-valve

[8] A.S.A.E.—Consulting engineer, International Motor Co., New York City.

[9] M.S.A.E.—Director of engineering, White Motor Co., Cleveland.

engine that usually determines the maximum mean effective pressure for a given displacement and mixture temperature.

There is no question that the exhaust side of the sleeve-valve engine runs much cooler than the center of the exhaust-valve head in a water-cooled engine. It would seem, however, that, due to the necessity for conducting heat away from the piston through the medium of two or three sliding joints theoretically separated by oil-films, the center of the piston-head would run much hotter than in a poppet-valve engine of the same dimensions. I am frankly skeptical as to the ability of either the single or the double-sleeve-valve engine in the larger sizes to give as good results in the hands of motorcoach or truck operators as is obtained today from a well-designed poppet-valve engine.

I hope Mr. Frederick, from his experience, can give us some definite information upon these phases of sleeve-valve engine-design.

MR. NIVEN:—Several of Mr. Church's points refer to the double-sleeve-valve engine and have regard to its use in truck or motorcoach work. Judging by the carbon deposit on the piston, it does not seem as if higher piston-head temperatures are met with in single-sleeve-valve engines, nor does the sleeve show overheating, a condition that certainly would be indicated on the sleeve, by distortion and discoloration, if not blistering; but these signs do not occur.

In the case of the single-sleeve-valve engine, in which there is not a localized hot exhaust-side, the sleeve moves up and around, covering a large surface between the two water-cooled walls of the head and the cylinder.

Lubrication has always been a problem in connection with the sleeve-valve engine, and one that has never received the attention that is due. In the case of the single-sleeve-valve engine, owing to the oil-spreading effect of the sleeve motion, together with reduction of oil-films, it is not necessary to provide the amount of oil that is necessary in a double-sleeve-valve engine; in fact, the one lubrication problem is to control the amount of oil reaching the sleeve. The Air Ministry Report, which was the result of tests on many different single-sleeve-valve engines of varying bores states that it is not necessary to have excessive oiling. If there is excessive oiling, it is a fault of the design of the engine, not a necessity.

J. A. ANGLADA[10]:—The question has occurred to most of us, Why has the poppet-valve engine not been superseded by a newer type? I think the answer is: We have employed thousands of capable engineering minds and have spent a great amount of money to improve the poppet-valve engine, because it is easier to do so than to institute research in a field in which the available data and experience are much more limited.

During the last 20 years, various non-poppet-valve engines have been built, most of them by men with limited engine-designing and building experience. The results of this work are not satisfactory because, with few exceptions, the engines are not so good as an ordinary low-priced poppet-valve engine.

The development of, or rather experimentation on, non-poppet-valve engines has followed five paths embracing the following groups or types of valves: (*a*) disc or plane valves, (*b*) plug or barrel valves, (*c*) cup or cap valves, having openings in their circumferences as well as in the head, (*d*) piston-valves, and (*e*) sleeve valves.

All these five types have appeared in various forms and have been driven to rotate continuously, to oscillate axially or circumferentially, or to have a combined oscillating and rotary movement. Structurally, the modifications of each type are very numerous; for example, flat or disc valves have been superimposed and driven in opposite directions, or have been formed as cones or sections of spheres. Attempts at neutralizing the cylinder-pressure against disc and cup valves have been tried and abandoned. So far as I know, the reason for the non-survival of the disc or cup-valve engine was the impossibility of keeping the valves tight after a brief period of service.

Plug or barrel valves of cylindrical or cone shape, arranged parallel with or at an angle with the stroke of the piston, have been experimented with to a greater extent than any other type. My experience with valves of this type has shown me the difficulty of keeping the valve cool enough to lubricate it properly and yet have the gas passages large enough to allow the engine to develop as much power as a good poppet-valve engine of the same displacement.

Piston-valves, either as a single valve per cylinder, or as separate inlet and exhaust-valves, or in combination with moving sleeves surrounding the valves, have been found deficient, because, if piston-valves are large enough, trouble with balancing and driving them results in complicated mechanism that unduly increases the dimensions of the engine.

Experience indicates that the most practical substitute for poppet valves is the sleeve valve surrounding the piston, or placed above the piston. Valves of this type do not distort excessively and provide sufficient cooling area to allow proper lubrication without waste of oil.

Several types of sleeve valve have been built and at present the double-reciprocating sleeve, or Knight type, and the oscillating single-sleeve, or Argyll type, are the best known. The reason is that both engineering and business sense have been used in their development and introduction.

Rotary sleeve-valves driven at constant speed give the simplest construction and are therefore to be preferred, though this type has not been manufactured commercially, so far as I know. However, in analyzing the construction of such an engine, it is feasible to design it so that it can be manufactured at a lower cost than the simplest form of poppet-valve engine.

Briefly, the advantages of sleeve-valve over poppet-valve engines are:

(1) Greater ability to withstand abuse and neglect and to continue to perform satisfactorily
(2) Greater silence and satisfaction after a long period of operation
(3) Greater power at high speed
(4) Smaller radiator-capacity
(5) Positive and permanent valve-action
(6) Ability to employ high compression
(7) Low maintenance-cost
(8) Smoother operation

The present disadvantages are:

(1) Greater weight
(2) Larger total dimensions
(3) Higher cost

It is my belief that the three disadvantages will be overcome within a short time, when silent valve engines will be in general use on cars, motorcoaches and trucks, and perhaps on higher powered engine-installations.

This is a broad statement, but, when we consider the rapid adoption of front-wheel brakes and balloon tires, the approval of non-poppet-valve engines will be rapid and in line with natural progress as soon as manufacturers have more experience with such engines.

[10] M.S.A.E.—Consulting engineer, New York City.

L. B. KIMBALL[11]:—I had the pleasure of adjusting an air-cooled four-cylinder engine and it cooled very well. This engine ran at a compression ratio of about 4.1 to 1.0, if I remember correctly, and was successful, except for the fact that the mechanism to operate the sleeve was a little heavy, causing an unbalanced force and undue vibration in the engine.

H. C. GIBSON[12]:—I am entirely in accord with Mr. Anglada's prophecy with regard to the sleeve-valve engine. He gave a little "boost" to the rotary sleeve. The carbonizing that was apparently necessary, according to Mr. Crane, with the sleeve-valve engine is not so serious as might be feared, inasmuch as the Knight sleeve-valve engine seems to get rid of its accumulation of carbon, particularly on the piston, which is one of the most serious places, inasmuch as it induces preignition, detonation, knocking, or whatever it is called, but the trouble that occurs is the carbonizing and filling up of the ports. That, of course, in a Knight engine is not so serious when the manifold can be taken off and the carbon disposed of by breaking it away and blowing it out.

I have had experience, as has Mr. Anglada, with rotating-sleeve engines in which a port in the rotating sleeve serves alternately for the intake and for the exhaust. I have found practically none of the "carbonizing up" in that engine. I should like to ask whether the same effect has been found with regard to the port of the Argyll engine that serves the double purpose, the central port in the Argyll engine being used alternately for the intake and the exhaust.

Mr. Church referred to the Argyll engine's smoking, in comparison with that of the Knight engine. It would be interesting to know what the oil consumption of the Argyll engine is in comparison with that of the Knight, because that is about the only fair comparison we have.

MR. NIVEN:—Under the official observation of the Royal Automobile Club in May, 1924, an Argyll car weighing 2721 lb., running weight, with a 91-cu. in. four-cylinder engine, showed an oil consumption of 1945 miles per gal., which, I think you will agree, is all that is desired.

As to the question of ports, we certainly find that the double-purpose port is not so prone to carbonizing as the exhaust-port, but we also find that the exhaust-port, in the case of the single-sleeve-valve engine, carbonizes a certain amount which then remains more or less constant under running conditions, that is, a layer of carbon about 1/32 in. deep gathers on the edge of the port, any surplus being blown out through the exhaust manifold. I am referring now to water-cooled engines. We have had air-cooled engines, as well, of course, as some of the poppet-valve type, that have given trouble by excessive carbonizing; the difficulty was usually overcome by making all the sleeve ports of the double-purpose type, as shown in Fig. 9. This arrangement of ports complicates manifolding.

A MEMBER:—What is the difference in mechanical efficiency between a twisting valve and the straight sliding-valve?

MR. NIVEN:—P. M. Heldt, in his recent paper[13] on sleeve-valve engines, pointed out that in a four-cylinder engine the primary unbalanced couple will not be neutralized, but the secondary forces will be. He stated that

With two sleeves, one of which leads the other by, say, 70 deg., the total unbalanced force on the double sleeve is greater by 64 per cent than on the single sleeve of the same weight.

I regret that no direct comparison tests of the mechanical efficiency of double and single-sleeve-valve engines are available.

P. M. HELDT[14]:—One thing that has been a puzzle to me in sleeve-valve engines is that they seem to have extreme timing of the valves. The exhaust is given as 60 deg. for the high-speed engine. I have noticed that in Knight engines the exhaust-valve also has a big lead and the inlet valve a big lag. I do not see why that should be so, as the opening seems to be quicker than with the poppet valve. In valve-opening diagrams of the sleeve-valve engine, the opening incline and the closing incline are straight lines, whereas those of the poppet-valve engine are curves, convex toward the base line. Why should that be? It is not made clear in the paper.

Mention was made in the paper of the hammer-blow in poppet-valve action. If there is any hammer-blow at all, it is due to the necessity for clearance between the valve and the push-rod. Otherwise, I think the forces involved in operating a poppet valve are considerably smaller than those involved in operating a sleeve valve. The forces of valve operation depend largely on the weight of the valve, which is undoubtedly larger in the case of sleeve valves. It also depends on the length of the stroke or the lift, and I believe that the stroke of the sleeve is about four times the lift of the average poppet-valve. In spite of that fact, the sleeve valve is at least as quiet as, and possibly more quiet than, the poppet valve. In the sleeve-valve engine, these forces are taken up on a large surface, whereas in the poppet valve, theoretically, there is a line contact between the cam and the cam-roller, or mushroom.

I should like also to refer to the increase in volumetric efficiency that was shown by the curves included in the paper. It was pointed out that the volumetric-efficiency curves were obtained when the air was drawn in cold. I think that is one of the explanations why the efficiency seems to be so high. In the poppet-valve engine, there is a great deal of heating of the incoming charge in the passages, because they are partly adjacent to the exhaust passages; but if the charges are preheated to 180 deg. fahr. before passing through the passages, I believe there would not be so much difference.

Another point raised was the holding up of the torque at high speed. That is partly accounted for by the unusual valve-timing. At low speed, power would be lost by reason of the early exhaust opening and the late inlet closing, the latter allowing some of the charge to be forced back through the inlet during the compression stroke. That may possibly account for the fact that the maximum torque occurs at a comparatively high speed.

MR. NIVEN:—In common with other engines, the valve-timing of single-sleeve-valve engines is determined by experiment. The early exhaust-opening quoted by Mr. Heldt was found to be the best on several racing-engines, and, judging by results, did not affect the intake efficiency at the higher engine-speeds. Obviously, it would not tend to give good torque at low engine-speeds.

The valve-timing used on commercial or passenger-car engines does not vary much from that on the usual poppet-valve engines.

Heating of the intake charge would lower the volumetric efficiency, but, in the case of the sleeve-valve engine, the heating of the intake can be under control.

Regarding inertia loading, A. J. Meyer, of the Con-

[11] M.S.A.E.—Research assistant, Mason Laboratory, Yale University, New Haven, Conn.

[12] M.S.A.E.—Consulting engineer, Engineering Developments, Inc., Philadelphia.

[13] See THE JOURNAL, March, 1926, p. 309.

[14] M.S.A.E.—Engineering editor, *Automotive Industries*, Philadelphia.

tinental Motors Corporation, recently analyzed the inertia cycle existing in our single-sleeve-valve engine, as shown in Fig. 3. It was found to differ considerably from that of an engine having reciprocating sleeves, there being no higher harmonics and the forces being the same at the top and the bottom centers. The inertia forces naturalize one another entirely. The only disturbing effect is a rocking-couple similar in character to that of a "tandem eight." The maximum inertia force was calculated to be 80 lb. per sleeve at 3000 r.p.m. and the maximum rocking-couple, 146 ft-lb. In a poppet-valve engine of similar displacement, the maximum inertia-force and rocking-couple were respectively 145 lb. per valve and 160 ft-lb., at a frequency eight times the crankshaft speed. It should be noted that poppet-valve inertias do not balance. The fact that the inertia force of a single-sleeve-valve engine is less than that of a poppet-valve engine is easily accounted for when one remembers that it is not the lift, but rather the acceleration of the masses, that counts.

A MEMBER:—I should like to give a layman's impression of the Argyll engine. In Detroit a few weeks ago and on the same day I rode in a motorcoach equipped with a steam engine, and in one equipped with a Continental experimental single-sleeve-valve engine, and also in a Vauxhall car equipped with an Argyll single-sleeve-valve engine. I think any rider's impression would be that the effect of the Argyll engine is very nearly like the steam powerplant. What problems are involved in making the $2\frac{3}{8}$-in.-cylinder engine operate successfully at 5000 r.p.m.?

MR. NIVEN:—The engine in question was not designed to run at 5000 r.p.m. To attain this speed, it would be necessary to alter the valve-timing, increase the intake areas, and probably lighten the reciprocating parts. The 91-cu. in. "Super-Sports" Argyll engine gave a power output of 52 b.hp. at 4500 r.p.m. on European gasoline.

O. A. ROSS[15]:—As a reply to the repeated question, "Why do sleeve-valve engines smoke while idling," may I suggest that the smoking of sleeve-valve engines during this period seems inevitable, for the reason that the high vacuum produced in the combustion-chamber tends to draw the lubricating-oil past the piston-rings into the chamber. This high vacuum is also transmitted to the inlet-valve chamber and, therefore, while the inlet valve is open, tends to draw lubricating-oil from between the outer wall of the sleeve and the cylinder-wall proper; this oil also eventually entering the combustion-chamber.

The use of sealing-rings between the sleeve and cylinder-wall has been suggested. Although these might tend to reduce the quantity of oil leaking past the sleeves, such rings, under certain conditions of operation of the engine, might prevent proper lubrication of the sleeves.

A new oil-rectifying system that removes the oil from between the sleeve and the cylinder has recently been placed on the market, but I do not know how effective it is in preventing the smoking of sleeve-valve engines during idling periods.

I believe that the smoking of sleeve-valve engines is objectionable only when the sleeves have become badly worn and allow large quantities of oil to leak into the combustion-chamber. Obviously, double-sleeve-valve engines will produce greater smoking than single-sleeve-valve engines.

MR. NIVEN:—Smoking in the Argyll engine is a question of controlling the oil passing to the outer and the inner surfaces of the sleeves. I pointed out earlier that this problem has not received much attention in the European engines until recent years. The Argyll company has recently made many tests with a view to cutting down the oil supply. The mileage per gallon that I gave, in reply to Mr. Gibson, is the result of these tests to baffle efficiently the oil splash from reaching the sleeve.

L. P. KALB[16]:—The remarks that have been made indicate some of the fundamental reasons why I looked with favor on this engine for some time before we acquired the patents. We all know that the trend of development of automotive engines has been toward greater output. Cars are now equipped with engines having less than 400-cu. in. piston-displacement that formerly had more than 600. Also, cars are now being handled with about 175 cu. in. that, 5 years ago, required more than 225. The increased engine output has been composed of two factors: increased mean effective pressure and higher operating-speed.

Mr. Hewitt has cited his experience in the matter of increased mean effective pressures. As we go over the power curves of the engines that we have built during the last 10 years, we note that each one of those power curves is a little better than those preceding. We have no reason to believe that this trend has reached the peak.

About 10 years ago a motor-car advertiser claimed that the last word had been said. Of course, we all consider that a joke now; and it would be just as absurd to assume that we shall continue to be satisfied with present outputs.

Mr. Crane brought up the point regarding the harshness of the Ricardo head. The Ricardo head has been very carefully worked out and is a scientific attempt to increase the mean effective pressure. Apparently the limitations of that particular head have been reached. We all know that most manufacturers would raise the compression if they could. But if they do, the cars are no longer acceptable to the public. Manufacturers of different types of poppet-valve engines seem to be almost at a standstill, unless the fuel characteristics are changed. The shape of the combustion-chamber of the sleeve-valve engine seems to be one of the most practical means by which we can continue our upward progress in the matter of mean effective pressure.

In the matter of engine-speeds, I believe we have about reached the limit of capability of the spring-actuated valve or of the cam-actuated valve. I happen to have been bothered by these problems in some high-output engines that we developed. I know how we attacked them and how others have attacked them. At high speeds, the trouble is caused by the synchronous vibration of spring coils. To reduce that vibration, we have increased the spring stresses and the spring-stress ranges until the springs are on the point of breaking, through fatigue. Fatigue, in the past, has not been the cause of spring breakage, but we are encountering it because the spring ranges are approaching that point.

I do not see how we can go farther; therefore, it has been my opinion for some time that a positively-operated valve is necessary, if we are to continue to increase the speed of the engine. The racing-car engine and the speed at which the valves operate may be cited, but I wish to assure you that the problem is very different from turning out hundreds of engines a day and of having them all go out and give the same performance. Therefore, I consider two things, the shape of the combustion-chamber and positive actuation of the valve, as being the two fundamental advantages that the sleeve valve possesses and that will allow a continued increase in the output per cubic inch.

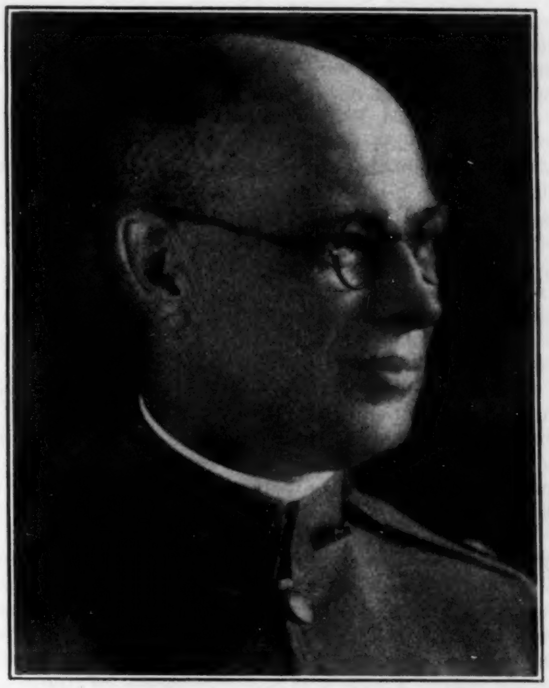
[15] M.S.A.E.—Consulting engineer, New York City.
[16] M.S.A.E.—Assistant chief engineer, Continental Motors Corporation, Detroit.

Colonel Burton to Resume Charge of Motor Transport Division

FRANK H. BURTON, formerly lieutenant-colonel in the United States Army, has been promoted to the grade of colonel, to rank from Feb. 15, 1927, and is to resume charge of the Motor Transport Division.

Colonel Burton was on duty in 1924 in the office of the Quartermaster General in charge of the Motor Transport Division but during the last year has been in the office of the Assistant Secretary of War, in the planning branch, as chief of the industrial division and chairman of the War Department Automotive Commodity Committee. He is to retain charge of the work of this Committee under the Assistant Secretary of War in addition to direction of the Motor Transport Division. In 1923, prior to his transfer to the City of Washington, he was chief of transportation of the Eighth Corps Area at Fort Sam Houston, Tex., and before that, from 1920 to 1922, was commanding officer of the Quartermaster Intermediate Depot for automotive equipment at Camp Normoyle, Tex. Through these two details Colonel Burton was in active charge of motor-transport operation, maintenance and repair work in the field and at the supply depot and gained a knowledge of and experience with the problems of motor-transport that qualified him well for his subsequent work in the offices of the Quartermaster General and the Assistant Secretary of War.

Colonel Burton succeeds Major Charles W. McClure, of the Quartermaster Corps, as head of the Motor Transport Division, since Major McClure has been obliged under the law to go on duty with troops. He has been a Service Member of the Society since September, 1924.



COL. FRANK H. BURTON

He was born in Port Ryerse, Ont., Canada, on April 16, 1868, but came to the United States with his parents while a minor and received a high-school education in Bay City, Mich.

THE LIMITATION OF OUTPUT

THE American people take pride in their relatively high standard of living, that is, in the fact that the average individual in this Country is able to enjoy the consumption and use of a much higher volume of useful goods and services than that of any other nation. Usually this happy circumstance is said to be the result of the higher comparative wage level of this Country. Actually the particular wage paid has nothing to do with it. The superior economic position of the American is due solely to the fact that our per capita production is much greater than that of any other nation, and consequently the per capita consumption has to be larger to dispose of it. If we produced no more per capita than other nations, our people on the average could live no better than the inhabitants of other countries, no matter how large their wages might be. While securing a balanced production is one of the most difficult problems with which industry and business is obliged to cope, production in the aggregate still lags far behind the possibilities of demand. Furthermore, each new discovery of science evolves new wants of a bewildering variety so that no sooner have we moved our living standards forward than the goal toward which we are aiming likewise advances and further widens the spread between our desires and our accomplishments.

A prominent national authority upon agricultural matters made the statement a few years ago that if the Nation's wheat crop had been planted, cultivated and harvested by the methods and appliances of 100 years ago, the process would have required a total expenditure of 130,000,000 man-days of human labor, whereas, with the modern facilities and procedure now available only about 7,000,000 man-days of human effort was actually consumed, an obvious saving in this single instance of 123,000,000 units of labor. Even if farm labor received no greater wage today than that paid 100 years ago, the employment of so large a proportion of the Country's available labor supply in this single field of endeavor would require that we should deprive ourselves of many comforts and luxuries, the creation of which has been made possible only because a sufficient volume of labor has been released from the task of producing the absolute necessities of life.

According to Government estimates an aggregate of mechanical power which is the equivalent of 250,000,000 human workers is now employed in the industries of this Country. When divided by the 40,000,000 persons gainfully employed, it will be seen that each employe on the average has the aid of approximately six mechanical assistants to help him in his work and to increase the productivity of his otherwise unaided hands. This is the basic explanation of the phenomenal record of progress that has been made by the industries of America.—C. R. Gow, before Allied Technical Societies of Boston.

AUTOMOBILE EXPORTS

MOTOR-VEHICLES have now become the most important product among exports of American manufactures. They are exceeded in value by shipments of only two commodities, cotton and petroleum. The field of potential buyers has been broadened by the reduction in cost and price that application of the best engineering skill and efficient methods have made possible. A vast amount of capital in the United States is seeking profitable use, some of which is finding an outlet in the establishment of assembly plants, sales organization and service stations in foreign countries. One of the chief manufacturing and export factors in this Country, for example, already has an overseas investment of $30,000,000 in plant, equipment, inventories, and working capital.

The United States and Canada are exporting almost as many motor-vehicles as they produced in 1913. This has been accomplished in the face of unfavorable economic conditions and low exchange-rates in many countries of the world and of the meager per capita wealth of the bulk of the earth's population. In addition competition from European manufacturers, particularly in their home markets, has made itself felt in no uncertain measure.

It has been estimated that the steel industry has earned barely 5 per cent of its capital investment in recent years. A number of the other important industries, while operating at a higher rate than the automotive, have not made exceptional earnings. For several years past the automotive industry has been foremost among all industries of comparable size in earning capacity. In the last 2 years estimated earnings by an important group of companies, exclusive of one leading factor, were approximately 25 per cent annually on stockholders' capital. The remarkable earning record of automobile manufacturers is some evidence of their ability to enter export markets in large volume, and the low rate of operation for the industry as a unit is evidence of the desirability of finding new outlets to take the overflow from the American market.

In the plants of body and parts manufacturers, according to the census of 1923, approximately 122,000 metal-working machines were installed, almost a machine for every man directly employed in that branch of the industry. Manufacturers of internal-combustion engines have about five machines to every eight men employed. In the plants of the motor-vehicle manufacturers of this Country will be found 126,000 metal-working machines, one to less than every two workers employed in this branch of the industry. Only one-fourth of this machine-tool equipment is over 10 years old, a vital factor in making the automobile virtually the lowest-priced manufactured product, in terms of dollar purchasing power, that can be bought in the American market.

The advent of motor-cars into every country of the world marks the beginning of a new era in transportation. Picturesque modes of travel by camel, ox-cart and the jinriksha used from time immemorial are going the way of the horse-drawn vehicles.

In 1926, the estimated National income in the United States was more than the entire national wealth of Germany. Per capita incomes in India, China and Russia, which contain a relatively large share of the world's population, are incomparably low. In those countries the automobile is in large measure still restricted to the wealthy class; far more so than was the case in the United States 15 or 20 years ago.

If it were an economic possibility for the per-capita ownership of cars in other countries to be as high as it is in the United States, the total motor-vehicle registration of the world would be over 340,000,000 as compared with present world registration of 27,508,000. Such a figure will never be approached simply because few parts of the world have been so abundantly blessed with mineral and agricultural wealth that they can afford to devote such an extensive portion of their resources to personal transportation. However, registration in the rest of the world is increasing at a far more rapid rate than in this Country. In 1922 world registration exclusive of the United States was 2,083,000. At the beginning of 1927, the estimated figure was 5,461,000, an increase of 162 per cent in 5 years. The increase in the United States in the same period was 110 per cent. The greatest actual increase in registrations during 1926 occurred in the United States, but the gain over registration in the previous year was only 11 per cent. The gain last year in the rest of the world was nearly 19 per cent. For individual continents the gains in Africa, Asia, Oceania, and Europe were 30, 23, 22, and 16 per cent respectively.

Wherever progress is being made American automobiles are in demand. The international movement for good roads is a direct outgrowth of motor-vehicle transportation and the combined effect of the two on expansion of automobile exports is incalculable. The international market for automobiles may be divided roughly into three groups or types of countries. Those of older industrial development, such as the manufacturing nations of Europe, have their own automotive industries, and while they are important buyers of foreign cars they are also growing competitors for other foreign business.

The second group comprises new countries, rich in raw materials, undergoing rapid development and possessing relatively high purchasing-power. These countries naturally are at present the chief markets in the international field. Although exports of American automobiles and motor-trucks in 1926 were distributed throughout more than 100 countries, five took over half the total exports last year. These countries, in order of importance, were Australia, Canada, Argentina, Brazil, and British Africa.

The third group includes old nations of dense population, relatively backward economic development and very low wealth and income per capita, countries of which China and British India afford examples. They provide only limited possibilities at present, despite their enormous population. However, this situation does not necessarily forestall a considerable future development of such markets. Many of them are rich in resources. There is evidence that a great change is occurring in the economic outlook of Asiatic countries. As industries gradually make their way into these non-industrialized areas, whether for purposes of exploitation of raw materials or for manufacturing, traditions gradually give way to progress.

The average price of passenger-cars exported from the United States in 1926 was $740 and that of motor-trucks was $705. Last year the average price of passenger-cars exported from France was about $1,374. The average price of motor-trucks was the same as of passenger cars. The average price of passenger-cars exported from Germany was approximately $1,600 and of motor-trucks $2,700. Great Britain is in a stronger position in passenger-automobile trade from the viewpoint of price competition than either France or Germany. The average price of passenger-cars exported last year was somewhat over $1,000, while prices of motor-trucks were around $2,400. The general high average-price of European passenger-cars and motor-trucks is due in part to higher production costs in Europe. The average price of Italian cars and motor-trucks exported last year was around $800, which indicates that Italian exporters are the only competitor in foreign markets in the same price-class as the American exporters.

The same broad policy of service as the foundation of permanent business relations is being applied by American enterprise in foreign as well as in domestic markets. One company alone, through establishing 40,000 service-stations in 104 countries, has made it possible for the owner of one of its cars to feel at home anywhere. Last year exports of parts for replacement and accessories amounted to over $45,000,000, or 14 per cent of total automotive exports.

Already American automobile manufacturers have 22 assembly plants in foreign countries, in which 175,000 cars of American types were assembled last year. In 1924 only 10 such plants were in existence. A combination in foreign countries of American capital and efficient production methods, relatively cheap labor and certain psychological advantages is certainly not without some degree of merit.—*Commerce Monthly.*

BRAKES AND BRAKE-TESTING SAFETY-CODE

THE Sectional Committee on Safety-Code for Brakes and Brake Testing, sponsored by the American Automobile Association and the Bureau of Standards and working under the rules of procedure of the American Engineering Standards Committee, has approved a report in the form of a code for use by the various States in regulating the brakes and brake testing of all motor-vehicles. The members of this Committee representing the Society of Automotive Engineers are the following: Clarence Carson, R. E. Fielder, C. L. Sheppy, and J. R. Cautley.

"Independently operated brakes" are defined as those having at least two means of operation, each of which means shall apply braking effort to at least two wheels, the braking mechanism being so constructed that no part which is likely to fail shall be common to the two.

The draft of code provides that, except in certain specified cases, all new motor-vehicles shall conform to its provisions and that equipment on motor-vehicles in service prior to the date of the code taking effect shall be modified. It is suggested that the code itself shall become effective 6 months after its adoption.

General Requirements

The general requirements are that all motor-vehicles shall be equipped with independently operated brakes of specified stopping-ability. Motorcycles, unless used in the transportation of passengers for hire, need be equipped with one brake only.

Electric vehicles purchased prior to the time of the code becoming effective need not have independently operated brakes but must meet the foot-brake and other requirements.

At least one brake shall be retainable in such a position as to restrain the vehicle from moving.

All testing is to be conducted with the clutch disengaged, except that in the case of a motor-vehicle that is not provided with a clutch the testing shall be done without power being applied to the driving-wheels, aside from cases in which electrical brakes are tested.

Every motor-vehicle weighing 6000 lb. gross or less, with specified exceptions, and every motor-vehicle for carrying passengers, regardless of its gross weight, must, according to the draft of code, be equipped with a foot-brake capable of stopping them from a speed of 20 m.p.h. within a distance of 50 ft., or at a corresponding rate; and with a hand-brake capable of stopping them from the same rate of speed within a distance of 75 ft., or at a corresponding rate. In both cases the specified condition for the stopping ability is a dry, hard, level road, free from loose material.

With reference to vehicles of more than 6000-lb. gross weight, for transporting goods or materials, tractors and all other motor-vehicles not mentioned in the preceding paragraphs, it is recommended that during the 2-year period following the adoption of the code, they, operating singly or in combination, shall be capable of stopping under the condition specified above within the following distances, or corresponding rates:

(1) Within 50 ft. from 20 m.p.h. upon simultaneous application of two brakes
(2) Within 75 ft. from 20 m.p.h. upon application of the foot-brake alone
(3) Within 75 ft. from 20 m.p.h. upon application of the hand-brake alone

Subsequent to the 2-year period following the adoption of the code, the requirements for the vehicles mentioned in the last paragraph above shall accord with the requirements relating to motor-vehicles weighing 6000 lb. or less and passenger carrying vehicles in general.

When vehicles are operated in combination, the "application of brakes" is to be construed to mean the application of all brakes on any vehicles of the train normally capable of being operated simultaneously by the driver.

Basis of the Code

While it is realized that many of the provisions of the code are not as stringent as they might have been made, the Committee believes that greater compliance, and hence greater safety, are likely to be obtained with its provisions than would be the case if they were made stricter. A comment accompanying the report is that "Should four-wheel brakes become universally adopted, revisions of the code would doubtless be both necessary and expedient." It is stated that it appeared from an analysis of test data that 75 per cent of the vehicles of more than 6000-lb. gross weight for transporting goods or materials, tractors and other motor-vehicles, were incapable, as operating at the time of test, of meeting the requirements specified for motor-vehicles weighing 6000 lb. or less and passenger carrying vehicles; but that there is no reason why eventually the same requirements should not be specified for all vehicles regardless of gross weight.

The motor-vehicles that constitute about 95 per cent of the road traffic, namely, those of 6000-lb. gross weight or less and passenger carrying vehicles, are, it is stated, capable of meeting the requirements specified for them; also, a considerable percentage of such vehicles already meet these requirements.

The rates, expressed in various units, corresponding to a stopping-distance of 50 ft. from 20 m.p.h., are 8.60 ft. per sec. per sec. or 5.88 m.p.h. per sec.

The performance required for hand-brakes is that which corresponds to an ability to hold a vehicle on a grade of more than 10 per cent.

SELECTING AN AIR-CLEANER

IN the discussion of the paper by Prof. A. H. Hoffman bearing this title, which was printed in the March, 1927, issue of THE JOURNAL, attention is called to an error on p. 395. C. A. Winslow states that he was the Member who spoke and that he said, "We have tried to determine whether centrifugal action took out the smaller particles. Centrifugal action acts better on large particles than on the smaller ones."

TOM S. SLIGH, Jr.

MEMBERS of the Society who knew him personally or have heard him speak at meetings of the Society and have read his papers on fuel and oil research in THE JOURNAL, were much shocked by or will learn herein with deep regret of the death of Tom S. Sligh, Jr., on March 30 by the accidental discharge of a revolver he was cleaning and reassembling. The accident occurred in his new home in South Bend, Ind., into which he had just moved his household effects after removal from the City of Washington following his appointment early in the year as physicist and assistant to William S. James, head of the research department of the Studebaker Corporation of America.

He was alone in the house at the time and nothing was known of the accident until the forenoon of March 31, when furniture movers found the body in a bedroom on the second floor. Investigation of evidence in the room indicated that he was shot sometime between 6 and 12 p. m. the night before. Mrs. Sligh, who was in the City of Washington at the time, did not return until the following Sunday. Death was caused by a bullet wound above the left eye. The revolver was found on the floor, and on a trunk near by were a bottle of gun oil, a cleaning rod, a screw that had been removed from the firearm, and the box in which the revolver had been packed when purchased a short time before. Lights were still burning in the room. The new house had been bought only a month before and some new furniture was being moved in.

Mr. Sligh was elected to membership in the Society in April, 1925, with the grade of Member, and was at that time physicist at the Bureau of Standards. He has become well known to members through his research work with hydrocarbon fuels and petroleum lubricating-oils. Papers delivered by him at national meetings of the Society and printed in THE JOURNAL include Measuring the Percentage of Crankcase-Oil Dilution, in the March, 1925, issue; Gasoline Volatility, in the April, 1926, issue, and Volatility Tests for Automotive Fuels, in the August, 1926, issue.

Mr. Sligh was born at Ruston, La., May 17, 1890, and received the degree of electrical engineer at the Louisiana State University in 1911 and the degree of master of science at Pennsylvania State College in 1912. He was a member of the American Physical Society, the American Society for Testing Materials, the American Optical Society, and the Philosophical Society of Washington. From 1911 to 1917 he was assistant professor of physics at Pennsylvania State College and from 1917 to 1926 was physicist at the Bureau of Standards, where he was engaged in measurements of heat and temperature and later in research work for the Bureau of Standards and the Society in connection with the lubrication of automotive engines.

COL. JAMES W. FURLOW

COL. JAMES WADSWORTH FURLOW, U. S. A. (retired) died at Pittsburgh on March 4, 1927. He was buried in the Arlington National Cemetery.

Colonel Furlow was born at Americus, Ga., Aug. 4, 1872. He was graduated from the Georgia School of Technology at Atlanta at the age of 16 years and entered the employ of the Georgia & Alabama Railway in 1888, as an apprentice in the locomotive repair-shops. Later, his work took him into civil engineering and in 1892 he entered the National Military Academy at West Point, receiving his commission in 1899. He served in the Philippine Island Insurrection and in the Vera Cruz Expedition into Mexico.

During the World War Colonel Furlow was assigned to duty in the office of Quartermaster General in the City of Washington and the Distinguished Service Medal was awarded him for his work in forming and equipping the motorized transportation branch of the Army. He was made Deputy Chief of the Motor Transport Corps in August, 1919. He followed courses of instruction at the General Staff College, the Motor-Transport School and Field Artillery School until he was retired in October, 1924, owing to broken health. In 1926 he was made special representative of the United States Chain & Forging Co., with headquarters at Pittsburgh.

During his career Colonel Furlow was stationed in many parts of this Country, Porto Rico, Cuba and the Philippines, and everywhere he had many friends. His wife and young daughter reside in the City of Washington.

Colonel Furlow was elected to Member grade in the Society on April 17, 1917.

CONSUMPTION OF FUEL OIL BY LOCOMOTIVES

A TOTAL of 59,682,000 bbl. of fuel oil was consumed by locomotives of the principal railroads in the United States in 1926, compared with 59,790,000 bbl. in 1925, according to returns received from railroads by the American Petroleum Institute. These figures include fuel oil consumed in all classes of service and are practically complete for all roads using fuel oil, only a few small lines consuming very little oil having failed to make returns. The total consumption of 59,682,000 bbl. in 1926 was made up of 54,980,000 bbl. of domestic fuel oil and 4,702,000 bbl. of foreign fuel oil. In 1925, of the total consumption of 59,790,000 bbl., 54,516,000 bbl. was domestic oil and 5,274,000 bbl. foreign fuel oil.

To separate the locomotive use of fuel oil by the usual railroad or Interstate Commerce Commission districts, has been found impracticable, but an attempt has been made to classify the use by geographical districts as follows: Eastern, Southern, Middlewestern and Southwestern, Southwestern Pacific and Northwestern. The largest consumption of fuel oil was shown in the Middlewestern and Southwestern district, totaling 29,717,000 bbl. in 1926, divided into 27,312,000 bbl. of domestic fuel oil and 2,405,000 bbl. of foreign fuel oil. This compares with 29,814,000 bbl. in 1925, of which 27,028,000 bbl. was domestic fuel oil and 2,813,000 bbl. foreign fuel oil. Consumption in the Southwestern Pacific district totaled 20,790,000 bbl. in 1926 compared with 20,926,000 bbl. in 1925, all this oil coming from domestic sources. In the Northwestern district consumption totaled 7,038,000 bbl. in 1926 compared with 6,637,000 bbl. in 1925.

Locomotives in the Southern district consumed 2,031,000 bbl. in 1926, compared with 2,272,000 bbl. in 1925, all foreign fuel oil. In the Eastern district the consumption totaled 106,000 bbl., of which 7000 bbl. was domestic fuel oil and 99,000 bbl. foreign fuel oil. This compares with 114,000 bbl. consumed in 1925 of which 7000 bbl. was domestic fuel oil and 107,000 bbl. foreign fuel oil.

Applicants *for* Membership

The applications for membership received between March 15 and April 15, 1927, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANTONSEN, ANKER KARL, designer, Fairbanks, Morse & Co., *Beloit, Wis.*

ARROUET, MARCEL, Chrysler Corporation, *Detroit.*

BANNISTER, BRYANT, power engineer, National Tube Co., *Pittsburgh.*

BILLINGS, GEORGE W., tool engineer, Nash Motors Co., *Kenosha, Wis.*

BOURKE, THOMAS N., assistant manager of the automotive division, Vanadium Corporation of America, *New York City.*

BOVEY, SIDNEY J. V., vice-president, Bovey Automobile Heater Co., *Chicago.*

BROWNING, A. H., superintendent, Laher Auto Spring Co., Inc., *San Francisco.*

BUBSER, FRANK, time and motion study, J. I. Case Threshing Machine Co., *Racine, Wis.*

CAMPBELL, WILLIAM JOHN, service superintendent, Seattle Automobile Co., *Seattle.*

CLARK, GEORGE L., professor of applied chemical research, Massachusetts Institute of Technology, *Cambridge.*

CROWLEY, A. J., sales department, American Car & Foundry Motors Co., *New York City.*

CUTTLER, LEONARD R., draftsman, Chandler-Cleveland Motors Corporation, *Cleveland.*

DAISLEY, ROBERT H., sales manager, Wilcox Products Corporation, *Detroit.*

DANNER, RICHARD, technical director, Oberursel works of the Duetz-Otto Corporation, *Oberursel, Germany.*

DAVIDSON, CHARLES B., service manager, Wood Motor Co., *Albuquerque, N. M.*

ELDER, JACK, chassis engineer, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

ELWELL, LLOYD E., chief draftsman, Western Machinery Co., *Los Angeles.*

EVANS, ALBERT DE VALOIS, truck and motorcoach division, General Motors Export Co., *New York City.*

FERRY, R. E., manager of manufacturing division, Standard Textile Products Co., *New York City.*

FLETCHER, HAROLD A., district service manager, Marmon Motor Car Co., *Indianapolis.*

FLYNN, LOREN T., technical service engineer, General Motors Truck Co., *Pontiac, Mich.*

FREED, BAYARD A., construction methods engineer, Pacific Telephone & Telegraph Co., *Seattle.*

FREY, C. P., engineer, Vacuum Oil Co., *New York City.*

GARDINER, A. T., general sales manager, Apollo Magneto Corporation, *Kingston, N. Y.*

GLANTON, K. H., sales manager, Dayton Rubber Mfg. Co., *Dayton, Ohio.*

GRUSS, FRANCIS, machinist, Gruss Air Spring Co. of America, *San Francisco.*

HAMMER, C. R., vice-president and treasurer, McCord Radiator & Mfg. Co., *Dayton, Ohio.*

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LANDEWEER, HARRY, engine inspector, Chandler Motor Car Co., *Cleveland.*

MACMILLAN, J. A., president and general manager, Dayton Rubber Co., *Dayton, Ohio.*

MADER, JOHN E., junior engineer, Coleman Motors Corporation, *Littleton, Colo.*

MEYERS, DAVID J., service manager, Copeland Refrigeration Co. of New York, Inc., *Brooklyn, N. Y.*

MIMRA, BOHUMIL, mechanical engineer, Autoplant "Tatra," *Koprivnice, Czechoslovakia.*

MINIER, S. I., manufacturer's agent, Simplex Piston Ring Co. of San Francisco, *San Francisco.*

MORRISON, R. L., representative, automotive division, Westinghouse Air Brake Co., *Detroit.*

MUZZY, MORRIS J., technical data secretary, General Motors Proving Ground, *Milford, Mich.*

NUTH, AUGUST C., Western sales manager, J. H. Williams & Co., *Chicago.*

OWENS, HAROLD E., mechanic, Anderson Aircraft Mfg. Co., *Anderson, Ind.*

PARKER, WILL D., research department, Phillips Petroleum Co., *Bartlesville, Okla.*

QUIN, E. A., tester, Rolls-Royce of America, Inc., *Springfield, Mass.*

RILEY, E. GEORGE, draftsman, Timken-Detroit Axle Co., *Detroit.*

ROBERTS, ADRIAN S., designing engineer, International Motor Co., *Long Island City, N. Y.*

ROBINSON, JOHN ATKINSON, layout draftsman, Buick Motor Co., *Flint, Mich.*

ROSE, FREDERICK L., superintendent of automobile maintenance, Abraham & Straus, Inc., *Brooklyn, N. Y.*

ROY, ERNEST R., chief block tester, International Motor Co., *Plainfield, N. J.*

RUMBALL, F. G., salesman, Timken Roller Bearing Co., *Cleveland.*

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SCHOTTERS, FRANK A., factory manager, Plymouth Body Works, *Plymouth, Ind.*

SCHRADER, H. W., automobile mechanic, 1432 Pallister Street, *Detroit.*

SHAW, HORACE P., vice-president and sales manager, Ramsey & Shaw, Inc., *Birmingham, Mich.*

SMITH, AL A. D., president, Grapho-Metal Packing Co., *Indianapolis.*

SMITH, J. HUGO, president, Wesson Sales Co., *Detroit.*

SNEED, JOHN, brake engineer, Midland Steel Products Co., *Detroit.*

SPEARS, H. M., chief metallurgist, Chevrolet Motor Co., *Detroit.*

SPEED, FREDERIC R., promotion engineer, Ethyl Gasoline Corporation, *New York City.*

SQUIRE, NUMAN T., general sales manager, Pocahontas Oil Co., *Cleveland.*

STRICKLAND, FREDERIC, Boynton Hall, *Bridlington, Yorkshire, England.*

SWENTZEL, F. J., mechanical superintendent, New England Transportation Co., *Providence, R. I.*

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VANCE, H. S., vice-president, Studebaker Corporation, *South Bend, Ind.*

VANCE, ORVILLE J., draftsman, Kelly-Springfield Truck & Bus Corporation, *Springfield, Ohio.*

WALLACE, W. A., special truck representative, International Harvester Co., *Jacksonville, Fla.*

WAMBACH, ALBRECHT G., assistant engineer, New York Telephone Co., *New York City.*

WETTLAUFER, ELMER G., designing engineer, Wilcox Products Corporation, *Saginaw, Mich.*

WILLIAMS, C. G., mechanical engineer, Sunstrand Engineering Co., *Rockford, Ill.*

WILSON, L. E., branch manager, Moreland Sales Corporation, *San Francisco.*

ZORGER, W. H., M.D., president, Zorger Lens Co., *Champaign, Ill.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 10, and April 9, 1927. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

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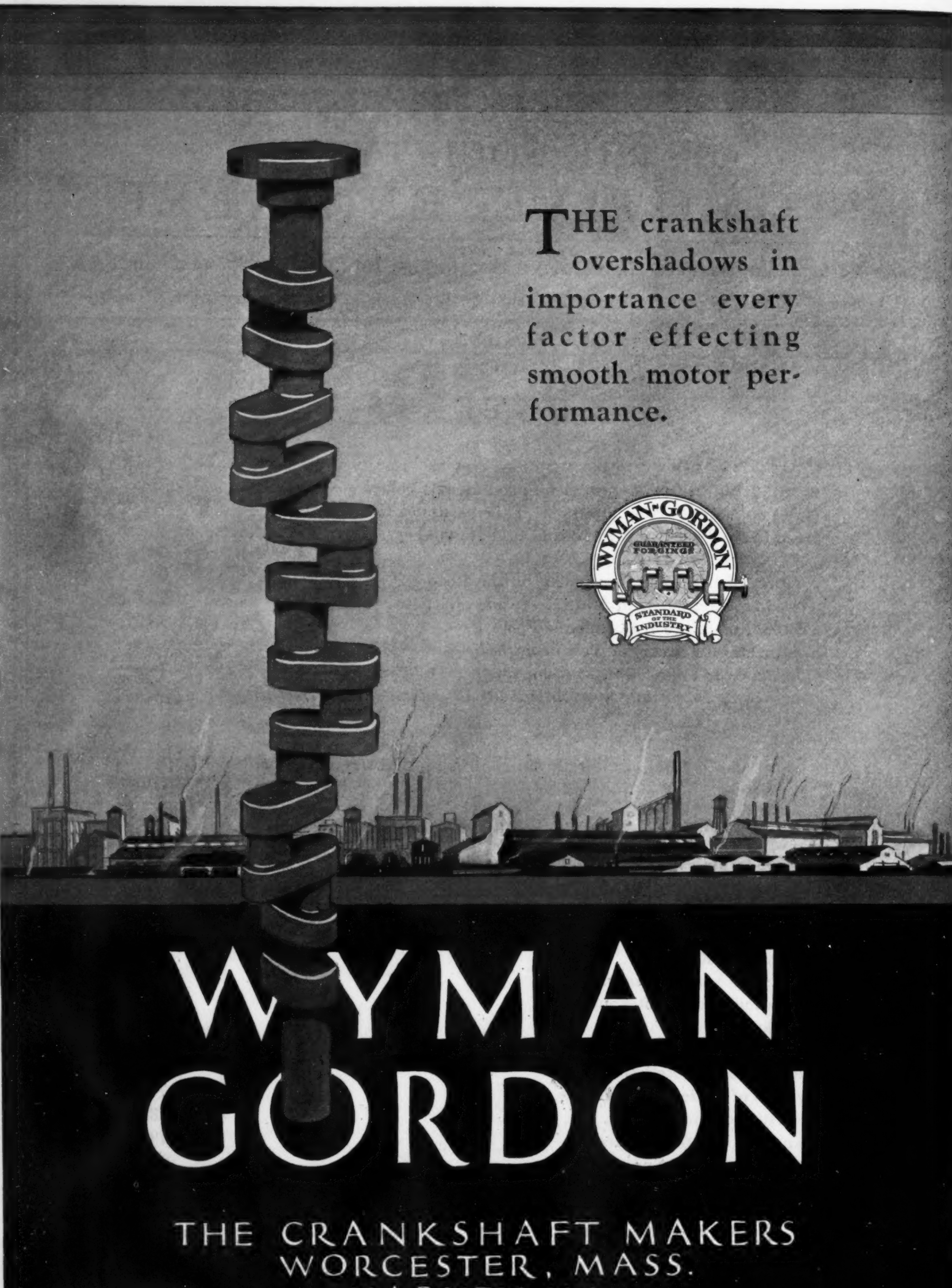
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